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C. W. THORNTHWAITE ASSOCIATES
LABORATORY OF CLIMATOLOGY

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The Shores of Megalopolis: Coastal Occupance and Human Adjustment to Flood Hazard

by

Ian Burton, Robert W. Kates, John R. Mather,
and Rodman E. Snead

U.S. Navy, Office of Naval Research

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C. W. THORNTHWAITE ASSOCIATES

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Ian Burton, Robert W. Kates, John R. Mather
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Final Report
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This study was inspired by the interest of C. Warren Thornthwaite in the shore of New Jersey where he made his home. Although he passed away shortly after this study commenced, it was because of his desire to apply to the problems of coastal occupance the skills of the physical and social scientists that the authors were first brought together. Made possible by financial support of the Office of Naval Research and the Corps of Engineers, this report is offered as further testimony to the breadth of C. Warren Thornthwaite's scientific vision.

The research on which this report is based was completed in two parts. The studies of coastal occupance in the face of storm hazards are a joint effort of Ian Burton, Robert W. Kates, and Rodman E. Snead and a team of research assistants assembled, in the main, from the Graduate School of Geography, Clark University. The studies of the climatology of damaging storms is the work of John R. Mather and his colleagues at C. W. Thornthwaite Associates, Laboratory of Climatology.

Robert W. Kates has written Chapters I, V, and VI, and shared in the preparation of Chapter IV with Rodman E. Snead. John R. Mather has written Chapter III with the help of his associates, Richard T. Field, Henry A. Adams, III, and Gary Yoshioka. The long Chapter II is a joint effort, written by Ian Burton with the assistance of Rodman E. Snead in the assessment of the natural environments of the study sites.

We gratefully acknowledge the assistance of our field party: Robert Arnold, Robert Gardula, Richard Hecock, and Roger Kasperson. They provided not only the bulk of the field data, but many insights, now securely incorporated within our own thinking. Robert Adams, George Downey, Nathan Meleen, Roger Roberge, and Carolyn Ryan all aided in processing our data at Clark University, Worcester, Massachusetts. Denise Baumann and Carol Ames helped with many secretarial chores, as did Lydia Burton, who as administrative assistant, took care of the administrative details in the Clark University office during the first year of the study.

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Finally, we would gratefully acknowledge the support and encouragement of the sponsoring agencies, the Office of Naval Research and the U.S. Corps of Engineers. They have provided us with the opportunity that the poet, Whittier, had at Hampton Beach for a "thoughtful hour of musing by the sea," and we hope our efforts have proved fruitful.

So then, beach, bluff and wave, farewell!
I Bear with me
No Token stone or glittering shell.
But long and oft shall Memory tell
Of this brief thoughtful hour of musing by
the Sea.

Ian Burton
Robert W. Kates
John R. Mather
Rodman E. Snead

June, 1965

CHAPTER I

A GEOGRAPHIC APPROACH TO COASTAL OCCUPANCE PROBLEMS

On March 4, 1962, a small storm was born between Florida and Bermuda as a wave on a cold front while a thousand miles away in the Mississippi Valley another storm was dying.[1] The prevailing upper air patterns suggested that the Florida storm would move safely out to sea and the one in the Mississippi Valley would proceed northward. Neither storm behaved as indicated. Instead, the Florida storm moved northward and the Mississippi Valley storm moved eastward meeting over the Cape Hatteras area and spawning the great Atlantic storm of March 6-7, 1962.

With the elongation of a nearly circular wind system, and with winds of 50 miles per hour blowing over a fetch upwards of 1,200 miles, a storm surge developed that battered the coast of New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina through three successive high tides. The battering and erosive action over such a prolonged period caused damage of about $190,000,000 and an estimated loss of 34 lives. Before the storm was over it sent swells southward to the Florida coast causing heavy damage to shore installations there.

Convergence of Factors

Storm damage and crisis. The storm of March 6-7, 1962 focused the attention of the nation for a brief moment on the outer shore that borders the area of most intensive settlement in the United States. The span of such attention though is small, and the remote public quickly turns to other concerns. Local attention persists longer: for public agencies until commitments generated in the crisis of the storm are fulfilled, for communities until the process of rebuilding and reconstruction is completed, and for the few individuals who suffered deep and often uncompensable hurt, a very long time.

For the authors of this report, the storm also generated interest in problems of coastal occupance. But this study would probably have not been undertaken except for a convergence of other factors. These indicated that there was a special utility in seeking a geographic approach to coastal occupance problems.

Flood plain studies. Beginning with the publication in 1945 of White's classic treatise on Human Adjustment to Floods, there has emanated from the University of

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[1]U. S. House of Representatives, Improvement of Storm Forecasting Procedures, Hearing before the Subcommittee on Oceanography of the Committee on Merchant Marine and Fisheries, 87th Congress, 2nd Session, April 4, 1962; and John Q. Steward, "The Great Atlantic Coast Tides of 5-8 March 1962, Weatherwise, Vol. 15, No. 3, June 1962, pp. 117-120.

Chicago a set of studies dealing with flood plain occupance in the United States.[1] These studies have grown in detail and sophistication; they have stimulated valuable work elsewhere,[2] but their basic theme remains, much as White suggested in his original work. Flood plain occupance represents an interaction between the requirements of a human system with its economic, social, and geographical relationships, and a hydrologic system marked by strong elements of uncertainty. In such a complex system, the optimal pattern of occupance is not easily generalized or even identified. But the choice of a pattern is much improved by considering the whole range of possible adjustments. These include such things as modification of the river's regime as well as the guiding and changing of human activities.

Two of the authors have been deeply involved in these flood plain studies and, at the time of the storm, had begun to think about the relationship between flood hazard adjustment and other types of natural hazard problems.

The natural hazard syndrome. Why do men seek to locate in areas of current high natural hazard? What do they know and do about the hazard? How does this compare with what they might know or do if they shared in the most advanced current scientific and technological knowledge? These are the kinds of questions that had been posed in the flood plain studies and seemed appropriate to ask more widely in areas of other natural hazards. In a classification of natural hazards, the notion was set forth that hazards of geophysical origin seem to have unique properties.[3] The magnitude of energy involved in geophysical hazards seem to place them beyond man's total control and thus there is a special need for a pattern of adjustment that seeks more than control of nature. An investigation of tidal or saltwater flooding appeared to be a very logical step in extending the flood plain studies to a new dimension while still retaining links in common with the previous studies and methodology. Thus when the storm occurred, the authors already possessed some previous experience in hazard investigation, a small body of theory, a

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[1] University of Chicago, Department of Geography, Research Papers: No. 29, Gilbert F. White, Human Adjustment to Floods: A Geographical Approach to the Flood Problem in the United States, 1942; No. 56, Francis C. Murphy, Regulating Flood-Plain Development, 1958; No. 57, Gilbert F. White, et al., Changes in Urban Occupance of Flood Plains in the United States, 1958; No. 65, John R. Sheaffer, Flood Proofing: An Element in a Flood Damage Reduction Program, 1960; No. 70, Gilbert F. White, et al., Papers on Flood Problems, 1961; No. 75, Ian Burton, Types of Agricultural Occupance of Flood Plains in the United States, 1962; No. 78, Robert W. Kates, Hazard and Choice Preception in Flood Plain Management, 1962; No. 93, Gilbert F. White, Choice of Adjustment to Floods, 1964; and No. 98, Robert W. Kates, Industrial Flood Losses: Damage Estimation in the Lehigh Valley, 1965.

[2] See the comprehensive bibliography published by the Tennessee Valley Authority, Flood Damage Prevention, An Indexed Bibliography (Knoxville: Tennessee Valley Authority, Technical Library, 1964).

[3] Ian Burton and Robert W. Kates, "The Perception of Natural Hazards in Resource Management," Natural Resources Journal, Vol. 3 (Jan. 1964), pp. 414-417.

larger set of empirical relationships, and a desire to extend existing insights to new areas. But, the regional relationships on the Eastern Seaboard pose a special challenge to geographers as well.

The growth of Megalopolis. From southern New Hampshire to northern Virginia live over 40 million people in a region of coalescing urban communities made famous by Jean Gottman's study of Megalopolis.[1] Here in less than 2 percent of the continental United States is found 21 percent of its people and an even higher proportion of its wealth. In the 1950-60 decade population increased by 18 percent, about the national average. But even faster than the increase in population is the growth of demand for outdoor recreation opportunities, many of which are found on the outer shore.

Pressures for shore development, the demand for recreation. It is estimated that the demand for outdoor recreation has increased in the post-war period at five times the rate of increase of population and income.[2] The major pressure for outdoor recreation in Megalopolis takes place on the shore. An investigation of recreation preferences of residents of the Delaware River Basin indicated marked preference for ocean beaches as the major outdoor recreation area.[3]

This pressure could be expected to have a marked effect on the expansion of development in shore areas and subsequent increase in damageable property. However, at the time of the March 6-7, 1962 storm, little was known about the rates of growth and development along the shore or about the other major problems of coastal occupance and human adjustment.

Major Problems

The growth and development of coastal occupance. Who locates close to the sea and why? What is the rate of growth of coastal settlement and what seems to be the major factors influencing this growth? Answers to these questions are basic to an understanding of the distribution and kinds of coastal occupance, and such understanding seems preliminary to any concern about the range of human adjustment to tidal flooding. Thus the first goal of any research strategy seemed to lie in this direction -- to measure the extent, rate, process, and possible consequences of the growth and development of coastal occupance.

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[1] Jean Gottman, Megalopolis, (Cambridge, M.I.T. Press, 1961).

[2] Marion Clawson, Land and Water for Recreation, (Chicago: Rand McNally, 1963), p. 36.

[3] U. S. Army, Corps of Engineers, U. S. Dept. of Interior, National Park Service, Report on the Comprehensive Survey of the Water Resources of Delaware River Basin, App. W. Recreation Needs and Appraisal, Philadelphia, 1960, p. W7.

Adjustment to hazard. In seeking to define improved patterns of coastal occupance, a prerequisite is the careful exploration of the range of possible adjustments to coastal storm hazard. Various agencies share responsibility for reducing damage from tidal flooding; some may warn, help evacuate, or build protective works. But the direction of a comprehensive program of damage reduction lies beyond the specific mission of any single agency and it is not surprising therefore that the potential for adjustment to hazard has never been systematically explored. Nor has the prevalence of damage reducing actions ever been estimated or even investigated.

Choice of alternative policies of development. Studies of occupance and adjustment are informative of the extent of major problems -- solutions, though, lie in the formulation of, and the choice between, alternative development policies. A basic consideration of the authors is to explore such alternative policies and the adequacy of the mechanisms for their implementation.

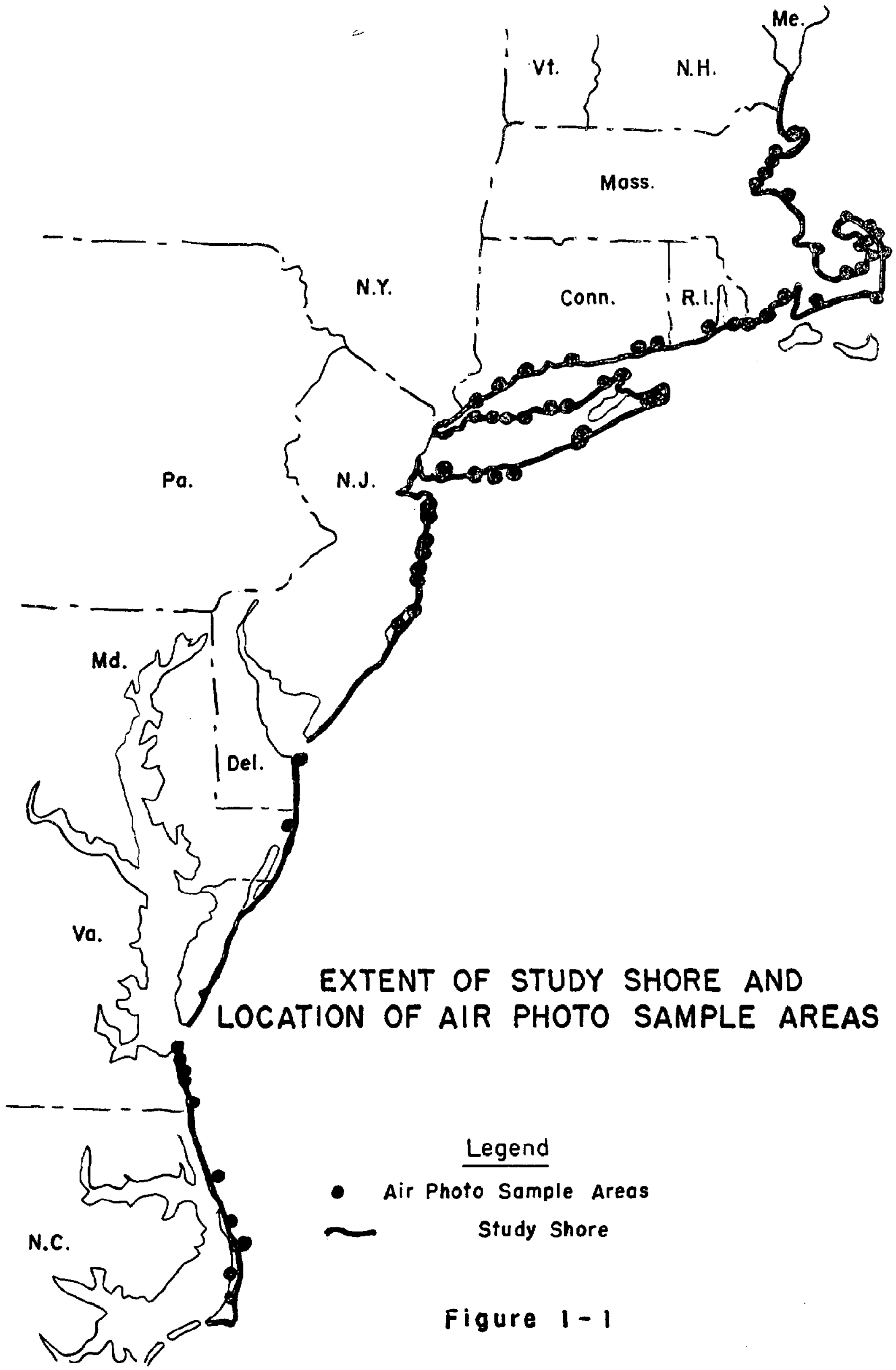
These then are the major problems considered in the geographical approach; the details of research strategy used to pursue them follow.

Research Strategy

The study shore. The convergence of factors that brought this study into being defined in part the areal extent of shore to be studied. As a study concerned primarily with tidal flooding, a focus on the outer shore seemed indicated. As a study concerned with the intensification of development under the pressures of urbanization, a focus on shore areas within the one-day recreational travel range of Megalopolis appeared desirable.

Various definitions of shore were investigated: generalized coastline, generalized tidal shoreline, and detailed tidal shoreline. None were available already delimited on maps; thus a special study shore was defined as a line along the outer fringe of the coast. First plotted on a 1:1,000,000 base map, it was subsequently transferred to standard 1:250,000 sheets from which all measurements used in the study (unless otherwise noted) were derived. Large water bodies were omitted as well as many large bays including Boston and New York harbors, Chesapeake Bay, the Delaware Estuary, etc. However, Long Island Sound was included. (See figure 1-1) The study shore, so derived, extends from the Maine-New Hampshire border to Cape Hatteras and covers about 1,302 miles in all.

Special studies were designed to provide a series of broad estimates for the entire reach of coast: 1) the real extent of hazard zones, 2) the climatology of damaging storms, 3) the amount and nature of coastal occupance and its change through time, and 4) the extent of damage and human adjustment to reduce damage. At the same time, and in some cases actually preceding these extensive studies, a series of intensive site investigations were undertaken to provide needed depth to the investigation.



EXTENT OF STUDY SHORE AND LOCATION OF AIR PHOTO SAMPLE AREAS

Figure 1-1

Extensive studies, the air photo sample. The basic tool for providing the initial estimates of the magnitude of the problem and measures of its intensification through time was a sample of air photos of the shore. The delimited study shore was stratified by states, and sample points were randomly chosen within each state according to the proportion of study shore lying within the state.

With the use of standard 9 x 9 air photos, it was hoped to have a minimum of two miles of coast on each sampled photo. To provide a desired 10 percent coverage of the study shore and to allow for losses and errors in obtaining photos, 68 points were chosen at random from the stratified sample. This expectation of loss was fulfilled, and in the final sample, 65 points were used, covering over-all 11 percent of the study shore, with a median length of exactly 2.0 miles each. (See table 1-1 and figure 1-1.)

Table 1-1

Characteristics of Air Photo Sample

Length of Study Shore . . . . .1302 miles
Length Sampled . . . . 144 miles

Distribution of Sample Areas

State	Number of Sample Areas	Percent of State Study Shore Sampled
New Hampshire-Mass.	19	13
Rhode Island	3	14
Connecticut	6	11
New York	16	10
New Jersey	8	11
Delaware	1	8
Maryland	1	5
Virginia	5	8
North Carolina	6	13
Total	65	11

Sample Area Size

Median Length (miles)	2.0
Range	1.1 - 10.7
Median Area (acres)	730
Range	102 - 3138

The air photos were to be used not only for measuring the amount of development but to provide rates of growth as well. Therefore, for each point, three sets of photos were sought: one taken in the pre-war period when extensive coverage began, one post-war with 1950 as the desired target year, and the most recent available photo. This turned out to be a most difficult and time-consuming task. Flight lines have been flown at different time intervals along even short stretches of coast and ownership and storage of photos is dispersed. The final sets of photos required assemblage from the holdings of the Departments of Agriculture and Defense, the U. S Coast and Geodetic Survey, the Geological Survey, and the National Archives.

Three-period coverage was obtained finally for 54 sample areas and for the remaining eleven areas two photos were combined with large scale topographic maps giving equivalent information. For many sample areas topographic sheets provided an additional observation in time as well.

Analysis of the air photos. The analysis of the air photos began with delimiting and measuring on the photos the following zones:

Zone A: Tidal, below the mean high water mark;
Zone B: Between mean high water and the 10-foot contour;
Zone C: Between the 10- and 20-foot contours;
Zone D: Above the 20-foot contour.

These zones were designed to approximate, in crude fashion, areas of varying hazard and were dictated by the available topographic coverage. However, they have some validity as an expression of actual hazard. The area below mean high water is, of course, a zone of almost daily inundation. The 10-foot contour approximates the maximum recorded tidal flood height in many areas; and the 20-foot contour contains the maximum area of water damage including splash and spray. Thus in a highly generalized sense, zone A is an area of intense hazard, B is the zone of the major hazard, and C is a zone of extremely rare hazard.

Within each zone, structures easily visible to the naked eye were counted as an indicator of occupance. The basic measurement of development of the shore was expressed in terms of the density of structures per acre, for each zone. A second measure of development, the proportion of shore frontage developed, was also obtained. This frontage was difficult to estimate because of the numerous indentations, tidal marshes, and streams. It was defined as land facing directly onto the open ocean or indentations which had direct access to open water. Each length of shore containing a structure within average lot size of the shore was considered developed. These basic measurements of area, structures, and developed shore frontage were repeated for each available time period. The results were plotted graphically and linear interpolations from these graphs gave a comparable set of measurements for three time periods -- 1940, 1950, and 1960.

Extensive studies: the climatology of damaging storms. A special study undertaken by one of the authors and his colleagues at the Laboratory of Climatology involved the assemblage of a distinctive climatology of damaging storms: occurrence, frequency, damage characteristics, and synoptic patterns. The results of this study are presented in Chapter III.

Extensive studies, other surveys. A collection of government studies of the shore were obtained and surveyed to provide estimates of tidal flood damage and the extent of protective works. A brief mail survey of the warning networks along the study shore was also made. A more elaborate extensive study requiring nine months and involving contact with 150 communities, to ascertain the extent of zoning and land use controls for reducing tidal flood damage was completed.

Intensive studies. The extensive studies provided first estimates of many of the components of the problems of coastal storm hazard. But in themselves they provided little understanding of the processes involved. For this purpose, more intensive investigations were designed. These case studies of various occupance situations involved upwards of five man-weeks of investigation each. For each of these study sites, data were obtained on the following: physical characteristics including hazard, an account of growth and development including settlement history, past and present land use, effects of protection measures, adjustments to hazard, and a prognosis of future development.

The fifteen study sites were not randomly chosen, but were selected from a much larger list of shore areas distinguished by the existence of published surveys and materials; estimates of hazard, maps, photos, tidal gage records, and the like. The strategy involved was to make fullest use of existing documentation and to use study personnel for investigations uniquely related to the problems of the study. From the list of some 71 possible sites, the fifteen chosen were to provide variation in region, hazard, physical type, and existing settlement. Three sites were almost adjacent to each other -- but different in other ways -- to provide comparisons within a common regional setting. (See figure 1-2 and tables 1-2, 1-3, 1-4.)

A variety of techniques were used to obtain the required data at each study site and these included mapping of landforms, hazard zones[1], and land use; structured interviews with beach users, seasonal and permanent residents, and commercial interests; and unstructured interviews with public officials, real estate men, construction firms, and sub-dividers. In all, over 1000 interviews were obtained.

The land use data that were collected involved the reconstruction of patterns of settlement in the past using aerial photographs and maps. The land use classification differed from conventional classifications since it was designed to study coastal occupance that is strongly characterized by a recreational and residential use. In this classification, transportation is associated with the land use that it serves; commercial, industrial, recreational, etc. The public classification includes quasi-public institutions

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[1] The hazard zones used in the intensive study are the same as used in the air photo analysis (p. 440) with the addition of Zone F: the zone of maximum tidal flooding.

Table 1-2

Physical Characteristics of Study Sites

No. Study Site	Size in Acres	Length of Coastline in Miles	Physical Type	Beach Width in Feet	Characteristics of Average Morphological Changes
1. Pt. Judith, R.I.	1750	8.3	Glacial plain	100-300	Cliffs stable beach retreating
2. Wellfleet, Mass.	2328	5.8	Morainic upland with cliffs	50-300	Cliffs and beach retreating
3. Villas, N.J.	222	1.3	Sand plain	100-200	Fairly stable
4. Chincoteague, Va.	3604	17.0	Barrier island	0-50	Fairly stable
5. Lynn-Nahant, Mass.	596	7.2	Glacial plain	0-300	Fairly stable
6. Fairfield, Conn.	1678	4.0	Glacial plain	0-150	Fairly stable
7. Hampton Beach, N.H.	2820	4.3	Barrier island	100-300	Cliffs stable beach retreating
8. Montauk, N.Y.	3238	8.4	Moranic upland with cliffs	50-200	Beach stable cliffs retreating
9. Sandy Hook, N.J.	1065	6.8	Barrier bar	0-400	Beach retreating
10. Cape May, N.J.	690	1.6	Sand plain	0-200	Beach retreating
11. Wildwood Crest, N.J.	995	3.7	Barrier island	300-500	Beach stable
12. Dennis, Mass.	2178	4.4	Glaçier plain	100-350	Beach stable
13. Nags Head, N.C.	3505	9.3	Barrier island	150-400	Beach retreating
14. Bethany Beach, Del.	3474	7.5	Sand plain & barrier bar	100-200	Beach retreating
15. Assateague, Va.	3400	7.1	Barrier bar	200-300	Beach retreating

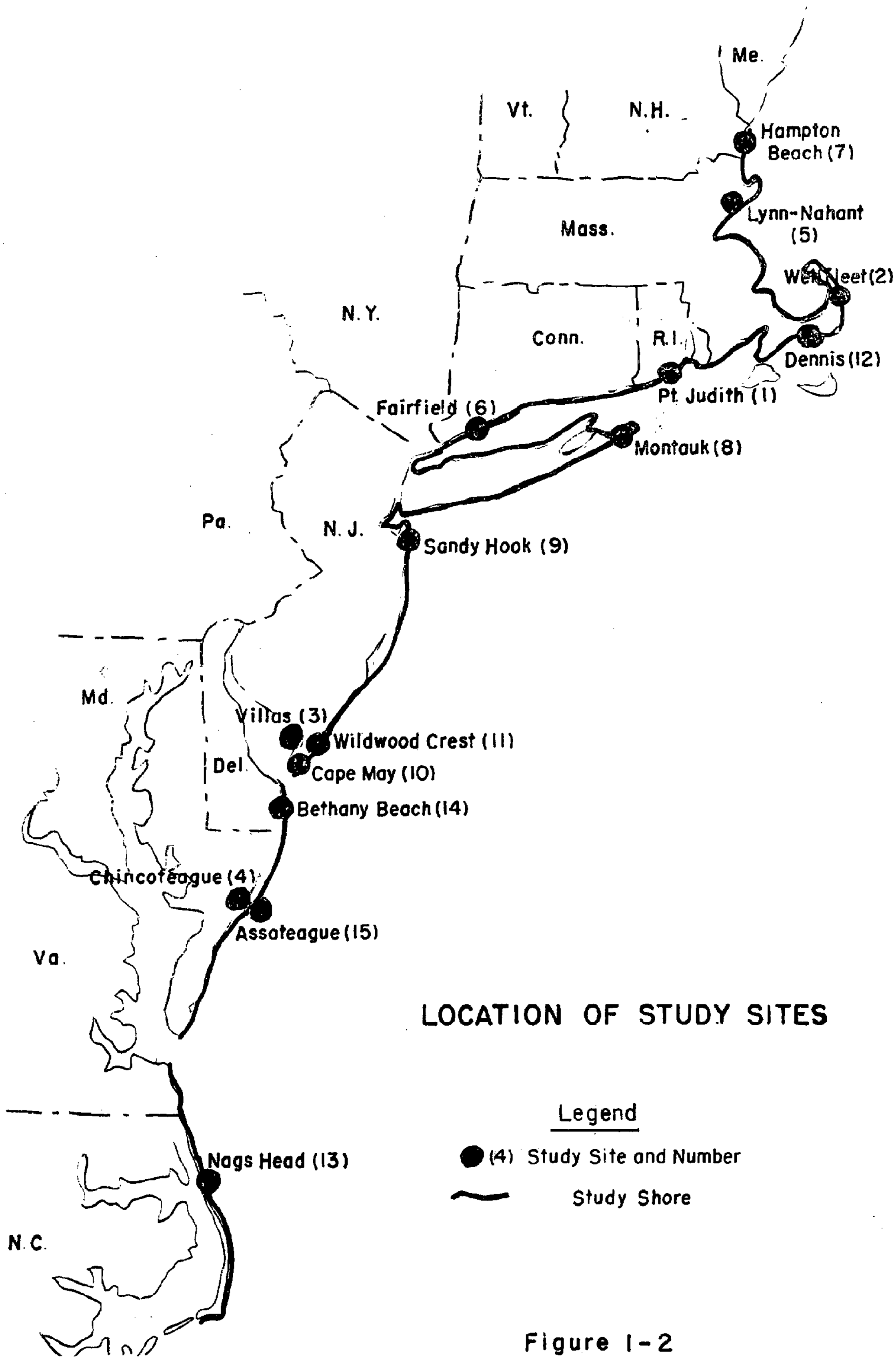
Me.
Vt.
N.H.
Hampton Beach (7)
Lynn-Nahant (5)
Mass.
Wellfleet(2)
N.Y.
Conn.
R.I.
Dennis(12)
Pt. Judith (1)
Fairfield (6)
Montauk (8)
Pa.
N. J.
Sandy Hook (9)
Md.
Villas (3)
Wildwood Crest (11)
Del.
Cape May (10)
Bethany Beach (14)
Chincoteague (4)
Assateague (15)
Va.
LOCATION OF STUDY SITES
Legend
(4) Study Site and Number
Study Shore
Nags Head (13)
N.C.

Figure 1-2

Table 1-3

Settlement Characteristics of Study Sites

No.	Study Site	Zonal Distribution of Study Sites in Percent: Zone A (Tidal Zone)	Zone B (Tide to 10 feet)	Zone C (10 to 20 feet)	Zone D (Above 20 feet)	No. of Structures	Over-all Density Structures per Acre	Occupance Type
1.	Pt. Judith	14	11	18	57	2018	1. 15	Village shore
2.	Wellfleet	16	7	17	60	402	0. 17	Village shore
3.	Villas	25	73	2		316	1. 42	Village shore
4.	Chincoteague	47	53			1509	0. 42	Village shore
5.	Lynn-Nahant	3	15	67	15	1142	1. 92	Urban shore
6.	Fairfield	16	47	20	17	1874	1. 12	Urban shore
7.	Hampton Beach	72	8	16	4	2360	0. 84	Summer shore
8.	Montauk	2	13	13	72	616	0. 19	Summer shore
9.	Sandy Hook	10	76	10	4	699	0. 66	Summer shore
10.	Cape May	1	78	21		949	1. 38	Summer shore
11.	Wildwood Crest	40	57	3		1057	1. 06	Summer shore
12.	Dennis	25	52	41	5	3942	1. 81	Summer shore
13.	Nags Head	22	52	20	6	871	0. 25	Summer shore
14.	Bethany Beach	10	85	5		1216	0. 35	Summer shore
15.	Assateague	26	34	3	37	6	0. 91	Empty shore

Table 1-4

Hazard Characteristics of Study Sites

No. Study Site	Number of Severe Storms[a]			Total 1935-64	Hurricane Frequency[b]	Approx. Height of Flood Record[c]	Percent Study Area Flooded
	1935-44	1945-54	1955-64				
1. Pt. Judith	1	3	5	9	0	9-13	25
2. Wellfleet	2	5	8	15	2	10-15	11
3. Villas	1	1	2	4	1	7- 9	39
4. Chincoteague	0	0	1	1	1	8-10	100
5. Lynn-Nahant	2	3	7	12	2	9-14	6
6. Fairfield	3	4	5	12	3	9-11	74
7. Hampton Beach	2	2	6	10	0	7-13	83
8. Montauk	3	4	5	12	3	8-10	9
9. Sandy Hook	3	1	2	6	1	8-10	64
10. Cape May	1	1	2	4	1	7- 9	69
11. Wildwood Crest	1	1	2	4	1	7- 9	68
12. Dennis	1	2	7	10	0	8- 9	48
13. Nags Head	1	1	4	6	9	10-15	86
14. Bethany Beach	0	0	1	1	1	7-11	95
15. Assateague	0	0	1	1	1	8-10	55

[a] See Chapter III for details. Frequency cited is for a 25 mile sector in which the study site was located.

[b] Frequency of hurricanes and tropical storms 1901-1955 that actually cross the coast in an 85 nautical mile sector within which the study site is found. Source was National Hurricane Research Project, Report No. 5 -- "Survey of Meteorological Factors Pertinent to Reduction of Loss of Life and Property in Hurricane Situations", U. S. Department of Commerce, Weather Bureau, Washington, March 1957.

[c] In feet, above mean sea level.

such as churches and excludes all public recreation. Recreational use distinguished between public and private ownership and for private ownership by the availability of public accesses. Residential use was further divided to provide information on the character of dwelling units. For clarity, some uses have been grouped on the maps included in this volume and this is shown as well in table 1-5.

Table 1-5

Land Use Classification Employed at Study Sites

Type Number	Land Use	Class Shown on Land Use Maps
1.	Industrial	Industrial
2.	Commercial	Commercial
3.	Public and Quasi-Public	Public
4.	Public Recreational	Recreational
5.	Private Recreational	Recreational
	a. With public access	
	b. Without public access	
6.	Residential	Residential
	a. Single family	
	b. Multiple family	
	c. Apartment block	
7.	Agricultural	Agricultural
8.	Undeveloped Land	Undeveloped

The results of the intensive studies are presented as a series of case studies in Chapter II and provide much of the data for Chapters IV and V. But before examining in detail the variety of patterns of occupance found on the study shore, it would be well to present the magnitude of that occupance derived from air photo samples.

Extent of Development Along the Study Shore

Structures as a measure of human occupance. The lowest common denominator of occupance used in the extensive survey is the density of structures visible on the 9 x 9 air photos. These structures may range from large chicken coops to factory buildings but they seem to provide a reliable index to human occupance of the shore and thus to damage potential.

The accuracy of sample estimates. The two measures that were used to make sample estimates of development are presented in tables 1-6 and 1-7. They are derived by the simple extrapolation of the total observations from the 65 sample areas. The basic assumption in presenting these estimates based on sample data is that the sample provides an unbiased estimate of the parameters of the study shore, density, and ocean frontage developed. The sampling method, because of constraints of data and funds, employs

Table 1-6

Sample Estimates of Area and Structures
Subject to Coastal Storm Hazard

	Hazard Zones A Tidal	B Tide-10 feet	C 10-20 feet
Area (acres)	59,370	196,490	83,690
1940			
Structures	4,700	68,800	45,200
Structures/acre	.08	.35	.54
1950			
Structures	7,100	86,500	56,900
Structures/acre	.12	.44	.68
1960			
Structures	9,500	114,000	70,300
Structures/acre	.16	.58	.84

Table 1-7

Sample Estimates of Percent of Ocean
Frontage Developed with Structures

Length of Study Shore	1,302 miles
Percent Developed Frontage	
1940	13.3
1950	17.0
1960	21.4

elements of simple random, stratified, and cluster sampling. Because of its underlying random selection process, the estimates appear unbiased. However, more important than the question of bias is the need to have an estimate of the variance. By what order of magnitude might the sample estimates differ from the true parameters? Such variance may be stated as an interval estimate at some fixed level of probability.

A statistical exploration of all the issues involved in estimating this interval is beyond the interest of this volume and possibly beyond the competence of the authors or even existing sample theory. A rigorous estimate of the variance would consider the 65 sample areas as point estimates of a finite universe of two-mile sectors[1]. If this was done the true proportion of ocean frontage developed in 1960, estimated from the sample as .214, might actually fall between .120 and .308 in 95 percent of the samples drawn in the same way.

The other extreme would be to assume that the independent observations were the approximately 100-foot units used in the estimate of frontage developed. In such a sample the true value of the proportion estimated by the sample proportion of .214 would fall between .205 and .222 in 95 percent of sample drawn in the same way.[2]

If sampling variability was the only source of error, the variance interval probably falls between these two extreme assumptions. But there are clerical and observational errors also and on the whole, these errors are probably biased towards underestimation. Structures were missed when obscured by foliage or poor photo quality and tend to coalesce in urban areas.

In sum these <u>caveats</u> suggest the following interpretation. The sample estimates are valued because they provide useful information available for the first time. They are probably accurate within an order of 25 percent. The greatest confidence may be placed in the variation in time and space that they provide, for here relative measurements -- growth over time -- densities in zones -- are stable and derived from the same consistent measurement process.

<u>Sample estimates of area and structures.</u> The critical hazard zones (A and B) below the ten-foot contour cover about 400 square miles or 255,860 acres, along the study shore. An additional 130 square miles (83,690 acres) lie between elevation 10 and 20 feet msl, an area of potential but rare hazard. Within this total area, 1-1/2 times the size of New York City, an estimated 200,000 structures could be found in 1960 and 125,000 were below the critical 10-foot contour. (See table 1-6)

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[1] Ignoring the variation in sample area size.

[2] Calculated by $p - 1.96 \sqrt{\frac{pq}{n} \frac{N-n}{N-1}} > P < p + 1.96 \sqrt{\frac{pq}{n} \frac{N-n}{N-1}}$ where P = true proportion, p = the sample estimate, q = 1 - p, N = the finite population, and n = the number of independent samples. In the first case n = 65, in the second case n = 7645.

The density of structures is low for the over-all area, never even reaching an average of one per acre. It is highest in the zone farthest from the shore and decreases towards the tidal zone. Hazard has some influence here in explaining this variation but other factors are surely important as well. Only specialized coastal activities appear to locate in the tidal zone, and much of it is undeveloped. Special problems of construction are encountered at very low elevations, including sewage disposal, and this discourages construction. More of the land at lower elevation is pre-empted for recreational use which require few structures.

But if the density of structures favors a lower incidence of damage in its spatial distribution the trend through time is disturbing. For there is clear indication that the rates of growth are highest in areas subject to greater tidal inundation damage. In table 1-8 the average growth rates are higher in the hazard-prone zones, with an average annual increase of 3.6 percent in the tidal zone for the 20-year period. The "ocean frontage developed" measurement involves frontage from all three zones but lies mainly in zone B.

Table 1-8

Indices and Rates of Growth for Study Shore and Adjacent Areas

	Indices 1940 = 100			Average Annual Growth Rates		
	1940	1950	1960	1940-50	1950-60	1940-60
Study Shore						
Structures/acre						
Zone A: Tidal	100	150	200	.043	.030	.036
Zone B: Tidal-10 feet	100	126	166	.024	.029	.026
Zone C: 10-20 feet	100	126	155	.024	.022	.023
Ocean Frontage						
Developed	100	128	161	.026	.024	.025
Adjacent Areas						
Coastal Counties						
Population	100	119	154	.018	.027	.023
Dwelling Units	100	125	170	.023	.032	.028
Megalopolis						
Population	100	112	133	.012	.018	.015
Dwelling Units	100	119	150	.018	.024	.021

The indices of development derived from the sample estimates are also compared with indicators from adjacent areas in an effort to see whether the growth along the shore has been unprecedented. Dwelling units are used as a crude approximation for comparison with the number of structures counted in the sample estimates. These data suggest that growth of the coastal counties exceeds the rest of Megalopolis, but growth on the outer shore does not appear to be excessive in comparison to the surrounding coastal counties.

Structures provide only crude estimates of occupance, but they could not be differentiated from the air photos. However, the land use data collected for the intensive studies can be used to suggest the over-all variation in occupance. These are presented in table 1-9 as a composite distribution. The density of structures is more intense in the study sites than the sample areas, as the former were chosen, with one exception, to provide areas of use rather than empty shore. But there is no reason to think that the relative distribution shown in table 1-9 is a-typical of coastal occupance.

Table 1-9

Composite Distribution of Land Uses by Hazard Zones,
15 Study Sites, 1963

Land Uses	Percentage of Total Within Each Zone									
	Zone A		Zone B		Zone C		Zone D		Zone F	
	Acres	Strs.	Acres	Strs.	Acres	Strs.	Acres	Strs.	Acres	Strs.
(1) Industrial			1.1	0.7	2.8	1.0			0.3	0.7
(2) Commercial			4.1	13.0	7.0	16.3	2.2	8.2	2.6	15.2
(3) Public Buildings	4.4	18.2	3.5	1.5	1.7	0.6	0.6	0.7	3.6	1.3
(4) Public Recreation	3.1		12.8		4.7	0.2	12.4		9.1	
(5) Private Recreation	2.0	9.1	3.8	0.3	1.8	0.1	0.6	0.2	3.3	0.3
(6) Residential	0.2	72.7	25.8	83.2	36.2	81.5	21.4	90.8	14.9	80.8
(7) Agriculture			1.9	1.3	4.8	0.2	3.2	0.1	1.3	1.7
(8) Undeveloped	90.0		47.0		41.1		59.8		65.0	
Totals (percent)	100.0	100.0	100.0	100.0	100.0	99.9	100.0	100.0	100.0	100.0
(number)	6,954	22	11,256	9,877	4,298	6,631	5,752	2,360	17,413	7,750

A high proportion of all land remains undeveloped and the dominant use is residential followed by recreational land use. Residential structures fill most of the developed land, with commercial structures a distant second. The variation in land use and development between zones does not seem significant except for the small amount of residential land use in the tidal zone and the lower densities previously noted.

In sum then, much of the study shore is still undeveloped: the rest is primarily used for recreation and associated residence and commerce. The distributions of structures favors less damage, but the differential in growth rates suggest increasing future damage on the equivalent of a large city that lies exposed to the sea below the 10-foot contour. These then are measures of extent and rates of change; an understanding of process requires a more intensive view.

CHAPTER II

PATTERNS OF COASTAL OCCUPANCE: A TYPOLOGY

The fifteen selected study sites have a wide range of hazard and settlement characteristics, and could be classified in a variety of ways. While it is not a purpose of this study to formulate a classification of coastal hazard and settlement situations that could be applied to all coastal areas, it is useful for descriptive and heuristic purposes to group the sites together into types. This typology is based principally on settlement characteristics and includes four types. These have been designated as the village shore, the urban shore, the summer shore, and the empty shore.

The village shore. Typically this is an old established form of coastal settlement in which fishing and agriculture are the chief means of livelihood. Recent decades are characterized by a decline in the importance of agriculture and commercial fishing, and a slow growth of sport fishing, and summer residential development primarily for recreational purposes.

The urban shore. Two of the case studies include densely developed urban areas. In these examples a long history of coastal settlement has been associated with the growth of a city and includes various activities that are more or less oriented to the sea.

The summer shore. By far the largest number of case studies are examples of summer residential settlements primarily established to utilize the recreational amenities of coastal areas. The formerly underdeveloped sections of coastline between villages and towns are now being rapidly developed as summer shore resorts.

The empty shore. This type refers to those rapidly diminishing stretches of coast that have not yet been incorporated into one of the other three types.

The fifteen case study sites are listed by settlement types in table 1-3. There are four examples of village shore, two of urban shore, eight of summer shore, and one case of empty shore. In each study a description of physiography and hazard has been included with a history of settlement and land use change to provide a prognosis of future change intensification and insights into the human use of the shore.

The Village Shore

1. Point Judith, Rhode Island[1]

Point Judith is a promontory on the western side of the mouth of Narragansett Bay. The study site extends along 8.3 miles of Rhode Island coastline between Moonstone

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[1] Field work by Robert Gardula and Roger Kasperson. We are indebted to the following person who supplied information; Mr. Cotter.

Beach on Block Island Sound and Black Point on Rhode Island Sound. Included are the southern part of Point Judith Neck, a wide peninsula which extends south along Narragansett Bay, and two large drowned embayments called Point Judith Pond and Potter Pond. A number of small fishing villages are found in the study area, namely, Point Judith, Galilee, Matunuk, and Snug Harbor. More recent communities include Scarborough Hills, and Carpenters Beach. (See figure 1 in the appendix. The site extends inland for two miles and its total area is 1,750 acres.

Physiography. Point Judith can be divided into three main physiographic types. About 83 percent of the area is characterized by a series of bedrock necks and scattered islands which rise slightly above the valleys and depressions which have been drowned by the sea. A thin veneer of glacial till covers these scattered sections of the mainland. Except in the north, the surface topography is gently rolling with hills reaching an elevation of 80 feet above mean sea level. The western part of the site beyond Potter Pond is a nearly flat plain with a thick soil cover. Much of this area is under cultivation right to the coast. The northern part of the study site forms part of the large Kingston moraine which is a continuation of the Inner or Harbor Hill moraine of Long Island that extends eastward under Long Island Sound and across central Rhode Island. The topography on this moraine is very rough with numerous small hills and depressions created by the meltwaters of the glacier and ice blocks left by the retreating glacier. A small section of this type of topography is found in the northern part of the Point Judith study site. Point Judith Pond and Potter Pond represent two large glacially scoured depressions which have been invaded by the sea to form irregularly shaped tidal marine estuaries with one narrow inlet from the sea. (See cross section, figure 2-1.) Numerous low rocky islands, and peninsulas divide these so-called "ponds" into many sections. If the sea had not invaded this region, these low areas would most probably be large fresh water lakes.

A second physiographic type making up 13 percent of this study site consists of small sections of widely scattered marshland behind the barrier spits near the coast and around the islands in the tidal estuaries. A few sections of the mainland, particularly on Point Judith Pond, have low swampy areas subject to inundation during severe storms.

Narrow sandy beaches from 150 to 200 feet wide constitute the remaining 4 percent of the study site. The widest and most gentle beaches are along Rhode Island Sound. Scarborough State Beach is three-quarters of a mile long and can be considered a bayhead beach because between the beaches are rocky headlands and offshore shoals. These bedrock outcrops are very dangerous to both ships and bathers. During severe storms both beaches and shoals take a heavy pounding from large storm waves.

On the Black Island side of the study site a sand spit has grown across Point Judith Sound forming a baymouth bar. The inlet or beachway which cuts through this sandbar connecting Point Judith Pond with the sea has been lined with jetties to keep the entrance stabilized. The projected depth through dredging is 14 feet. Large breakwaters built seaward from the beachway form the Point Judith Harbor of Refuge.

Materials which make up the Point Judith study site include thin tills, (clay and boulders) across the entire area with thicker morainic deposits in the north. Silts and clays are found in the bays and ponds. The narrow beach zone is composed of medium grained sands.

Most of the study site falls into two broad vegetation classes: mixed deciduous and coniferous forests and cropland. Areas near the water bodies have marsh grass or are without vegetation.

Storm hazard. The Point Judith study site has a high degree of hazard from coastal flooding. The Corps of Engineers report a flood of record in the 1938 hurricane at 12.3 feet above mean sea level.[1] Field interviews in 1963 indicated a flood of record ranging from 9.5 feet to 13 feet with most of the line of maximum inundation at approximately 12 feet above mean sea level.

Nine of the thirty-six storms recorded over a 30-year period resulted in heavy damage. The greatest damage is usually associated with hurricanes. The three most damaging storms are recalled by residents as the hurricanes of 1938, 1944 and 1954.[2] During the 1938 hurricane sections of the beach were cut away 25 feet with an over-all lowering of the beach 3 to 4 feet. Bluffs were cut back at least 20 feet with the eroded material washed inland. Sea walls and jetties were unable to check the waves. One hundred people lost their lives and about 1,000 cottages and buildings were destroyed, in the vicinity of Point Judith.

In all three storms, frontal structural damage with the undermining of foundations and destruction of grounds was a common feature along the immediate shore. Also, extensive marina and boat damage took place at the fishing village of Galilee, and many of the homes well behind the shore had flooded cellars.

Movement during such storms is dangerous because many roads become impassable as storm waters cross the sand barriers and flood the inner water bodies. The seawall which surrounds the harbor of refuge is overtopped in large storms and the fishing piers, such as Narragansett Pier on Long Island Sound, suffer heavy damage in major hurricanes. The Weather Bureau's Storm Surge Warning Maps[3] recommend evacuation of all low coastal areas during severe storms to high ground 15 to 20 feet above sea level.

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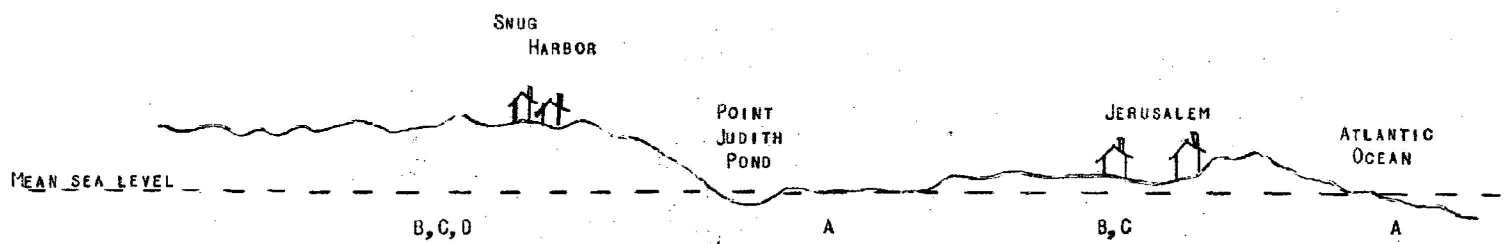
[1] U.S. Army Corps of Engineers, South Shore, State of Rhode Island Beach Erosion Control Study, 81st Congress, 2nd Sess., House Doc. 490, 1950, pp. 12-17, and U.S. Corps of Engineers, Beach Erosion Control Report on Cooperative Study, South Kingston and Westerly, Rhode Island, U.S. Army Engineer Division, New England Corps of Engineers, Boston, Mass., Nov. 13, 1957, pp. 3-5.

[2] U.S. Corps of Engineers, op. cit., South Shore, State of Rhode Island . . . . pp. 14-17.

[3] U.S. Department of Commerce, Weather Bureau, Storm Surge Warning Maps, Nos. 8 and 9, August, 1962.

STUDY SITE NO. 1



	B, C, D	A	B, C	A
ZONE	ABOVE MEAN HIGH TIDE TO OVER 20 FEET	BELOW MEAN HIGH TIDE	ABOVE MEAN HIGH TIDE WITH A FEW AREAS OVER 10 FEET	BELOW MEAN HIGH TIDE
GEOMORPHIC TYPE	DISSECTED UPLAND COVERED WITH SMALL HILLS AND DEPRESSIONS. BEDROCK COVERED WITH GLACIAL TILL	TIDAL MARSH AREA AND SALT WATER POND-SILTS AND CLAYS	SAND FLATS WITH LOW DUNES NEAR THE COAST. SOME FILL	SANDY BEACH WITH A NARROW SHELF OFF SHORE
TYPE OF HAZARD	SOME FLOODING IN AREAS NEAR THE PONDS	FLOODING DURING SEVERE STORMS	FLOODING AND SOME EROSION	FLOODING, EROSION AND DESTRUCTION OF STRUCTURES
DEGREE OF HAZARD	MINOR	MINOR	SEVERE, HEAVY DAMAGE	SEVERE, HEAVY DAMAGE
STRUCTURES	MOST OF UPLAND HAS FEW STRUCTURES EXCEPT AT SNUG HARBOR	FEW	MANY	FEW
ADJUSTMENTS	FEW	FEW	FILLING IN OF MARSH AREAS, ESCAPE ROAD, MANY INDIVIDUAL ADJUSTMENTS	JETTIES, BREAK-WATERS AND GROINS

FIGURE 2-1. DIAGRAMMATIC CROSS SECTION, POINT JUDITH, RHODE ISLAND

Coastal changes. Coastal changes at the Point Judith study site have resulted from storm action and human attempts to reduce their effects. Beaches, cliffs, and dunes are cut back during severe storms but the beach is usually restored during the summer months when calmer conditions prevail. However, there is a gradual over-all retreat of the coast taking place.

The largest structure built to keep off the fury of the storms is a large 10-foot high breakwater which surrounds the Point Judith Harbor of Refuge. The breakwater is over 2-1/2 miles in length and is divided into three sections allowing for two wide entrances to the enclosed area of about one square mile.

Settlement history. The area was included in a purchase of land from local Indians in 1657. Settlements began shortly thereafter and were at first largely agricultural in nature. South Kingston was set off and incorporated as a separate town in 1722.[1]

The fishing industry flourished during the 19th century and large catches of striped bass, white perch, smelt, and herring were taken from Point Judith Pond. In addition numerous fine quality oysters were marketed in Boston, Providence and Newport.

In recent decades the fishing industry has declined and has not been completely replaced in the local economy as a source of income by tourism.

Land use changes. There has been a steady population growth in the vicinity of Point Judith over the past 25 years. The population of Narragansett, the nearest minor civil division has grown from 1,560 in 1940 to 3,444 in 1960. This growth is reflected in an increase of single family residences in the study area from 1,729 in 1951 to 1,919 in 1963. This increase is mainly in the form of summer cottages. There has been no other growth in the area and in the case of some types of land use a decline has been recorded. A generalized map of land use is shown in the overlay of figure 1 (appendix). Recorded changes of land use are given in table 2-1.

Most of the new residential development has been out of the flood hazard area and above the 10-foot contour. Major growth has occurred in three areas. (1) North of Carpenter's settlement and beach, older established residential areas have been more densely developed. (2) East of Sand Hill Cove beach a subdivision has been nearly doubled in size. (3) Steady growth has occurred in the residential area to the west of Scarborough Beach.

Two settlements of cottages, trailers, and their associated camping grounds have fluctuated in size but are now approximately the same as in 1951.

Growth in the area has been stimulated by its accessibility via national routes 1 and 1A and by the attractions of sport fishing. The pace of activity is highly seasonal,

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[1] J. R. Cole, History of Washington and Kent Counties, Rhode Island. New York, W. W. Preston & Co., 1889.

Table 2-1

Point Judith, Rhode Island

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use[2]	No. Structures 1951	No. Structures 1963	No. Structures % change	No. Acres 1951	No. Acres 1963	No. Acres % change
A	8 Undeveloped	0	0	0	232	232	0
Tidal	Total	0	0	0	253	253	0
B	2 Commercial	31	31	0	12	13	+8
	6a Residential	244	263	+8	75	79	+5
	8 Undeveloped	19	0	na[3]	66	55	-17
Tidal-10'	Total	303	303	0	192	192	0
C	2 Commercial	25	25	0	5	7	+40
	6a Residential	789	808	+2	77	88	+14
	8 Undeveloped	67	0	na	137	124	-10
10'-20'	Total	887	839	-5	307	307	0
D	2 Commercial	16	16	0	2	2	0
	6a Residential	696	848	+22	207	276	+33
	7 Agricultural	0	0	0	184	170	-8
	8 Undeveloped	152	0	na	600	545	-9
> 20'	Total	876	876	0	998	998	0
F	2 Commercial	31	31	0	12	13	+8
	6a Residential	330	356	+8	77	81	+5
	7 Agricultural	0	0	0	3	3	0
	8 Undeveloped	26	0	na	294	287	-2
Flooded	Total	396	396	0	440	440	0
All Zones	1 Industrial	3	3	0	2	2	0
	2 Commercial	72	72	0	19	22	+16
	3 Public	11	11	0	5	5	0
	4 Recreational	2	2	0	35	43	+23
	5a Recreational	11	11	0	0	0	0
	5b Recreational	0	0	0	26	24	-8
	6a Residential	1729	1919	+11	361	445	+23
	7 Agricultural	0	0	0	267	253	-5
	8 Undeveloped	238	0	na	1035	956	-8
	Total	2066	2018	-2	1750	1750	0

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] See detailed land use classification, Table 1-5.
[3] na -- Calculation not appropriate.

however, and the commercial fishing industry is not large enough to support a big winter-time population. A local zoning ordinance may also have helped to inhibit coastal development.

Adjustments to hazard. There is a high level of awareness of the storm hazard in Point Judith and this is reflected in a high degree of adjustment in both public and private sectors. At the public level storm hazard areas have been plotted and a zoning ordinance is in force in South Kingston. This flood plain zoning ordinance is one of the very few of its kind in coastal areas, although such regulations are more common in riverine flood plains. The law stipulates that ". . . no floor for overnight human occupancy shall have an elevation of less than 20 feet above mean sea level." Some filling of marsh areas for residential development has taken place, but the new zoning law is likely to slow the pace of future development. A second public adjustment is the construction of a new road in 1955 by which the residents of Great Island and the fishing village of Galilee may escape to higher ground on Point Judith Neck. Known as the Escape Route this road is higher than the maximum flood of record.

In addition there are a number of private adjustments. Several new houses have been built on stilts; a small number of property owners have placed stone and concrete rip-rap or small home-made bulkheads at the front of their houses. One man has used snow fences and coniferous trees to help hold the sand dune in place.

These adjustments reflect a high degree of awareness and a fear of storm damage.

No one here expressed interest in going down to the shore "to see the water come up" as in Fairfield and Montauk. Rather, many inhabitants viewed life in Point Judith as distinctly risky. Since much of the development in the high hazards areas predates the 1954 storm many people had experienced damage from hurricane Carol in 1954. The heightened awareness also affects land use decisions although it is not easy to determine to what degree. The local zoning ordinance with its minimum requirements for floor elevation obviously has some effect, but many people are inclined to stay away from the most hazardous areas anyway. The feeling of insecurity in Point Judith is high. Many inhabitants expressed the need for more protection and complaints were made in Galilee and Jerusalem that escape route provisions were inadequate to prevent them being cut off in a high storm.

Evacuation is a common adjustment when storm warnings are received. Trailers on a camp site close to the beach are habitually towed to higher land half a mile away.

Future Development. The potential of the Point Judith area for further recreational development seems high. At present there are three state beaches comprising approximately 50 acres. Two of these which may be described as "family beaches" (Sand Hill Cove and East Matunuk) are seldom used to capacity and compared with many other beaches on the eastern seaboard they could accommodate many more people. The third beach (Scarborough) is predominantly used by teenagers.

In addition to the public beaches there are about five privately operated beach areas which also appeared to be highly used during the duration of field work in the area. The potential for further growth undoubtedly exists. Marinas and motels could be developed, but so far the wave of dense coastal development has not reached Point Judith which remains a village shore.

Much of the land that is potentially developable is in private ownership, some of it in farmland. Areas of public ownership include the Coast Guard Station at the tip of Point Judith and the U. S. Army Reservation off Point Judith road.

Point Judith typifies a not uncommon pattern of coastal development. The nuclei of historically important fishing villages provide cores around which recreational pursuits slowly grow as fishing and agriculture decline.

Severe damage in the past is associated with a high degree of awareness among present inhabitants and a wide range of adjustments to hazard. Moreover the adoption of a zoning ordinance for part of the area (South Kingston) gives some assurance that newcomers to the area will not move into high hazard areas in ignorance of the hazard. Further development is likely to be concentrated above the 10-foot contour, and a rapid increase in flood damage potential seems unlikely.

2. Wellfleet, Massachusetts[1]

Wellfleet is a village community on the outer Cape Cod peninsula. This second example of the village shore type of development is seven miles north of Orleans and ten miles south of Provincetown. The area of 2, 328 acres is shown in figure 2, 2a in the appendix. It includes Wellfleet Harbor on the Cape Cod Bay side of the peninsula and a stretch of the Cape Cod National Seashore on the Atlantic Ocean side.

Physiography. The largest part of the area (about 82 percent) consists of rolling hills and depressions with a relative relief of from 50 to 100 feet above mean sea level. A few sections of the study site reach 150 feet. This rolling upland represents a glacial moraine with scattered kames and kettle holes making a very irregular, poorly drained surface. The highest areas of the upland are on the eastern side where large kettle holes are filled with water forming rounded ponds such as Gull Pond, Great Pond, and Long Pond. Along the Atlantic coast a long, gently curving beach is backed by 50-to 100-foot high cliffs. On the western side of the study site the upland areas are more broken up with tidal marshes between the islands. Spits and bars project from the islands, and in some areas, nearly close off the tidal flats. The resulting coast on the west is a series of coves, bays, and harbors. Most of the shoreline in this region consists of narrow beaches backed by morainic cliffs that are slowly being cut back and smoothed by the waves and currents. No bedrock is exposed at the surface.

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[1] Field work by Robert Arnold and Richard Hecock. We are indebted to the following person who supplied information; Mr. William Douns.

Except for the town of Wellfleet which is situated on one of the inner bays, the uplands are largely unsettled. The very coarse tills made up of boulder clays are difficult to work and poorly drained. Most of the structures are residences found near the beaches or commercial structures along the major highways. Large sections of the Wellfleet study site are included in the new Cape Cod National Seashore which will be under development for a number of years.

The second major physiographic type is the marsh area which make up 13 percent of the study area. (See cross section, figure 2-2.) Through time the fine silts and clays have been removed from the uplands and carried into the tidal lagoons surrounding the islands. Extensive tidal flats have been changed into salt marshes and then into dry land with the help of both man and nature. Evidence that the coves and bays are filling exists as sailing ships, which used to be able to go in and out of Wellfleet harbor without difficulty, now need to follow narrow dredged channels.

Very little filling of the marsh areas for residential development has taken place. However, the construction of roads and railroads across the marshes has promoted filling. An example is along Herring River, where a road-railroad bridge, acting as a partial dam, has cut down the flow of tidal water into the inner marsh.

The third physiographic division, making up about 5 percent of the study site, consists of the beaches and sand dunes along the immediate coast. The 2.4 miles of beach on the Atlantic coast called La Count Hollow Beach and Cahoon Hollow Beach are representative of the beaches found along much of the Outer Cape. Morainic cliffs, in places 115 feet high, are almost vertical above a beach that averages 100 feet wide. Here is found some of the most spectacular coastal topography along the eastern coast of the United States.

In winter the beach not only retreats toward the cliffs, but very large waves and high tides will cross the beach and cut the cliffs back. John Zeigler and associates at the Woods Hole Oceanographic Institutiion have been studying the Outer Cape Cod beaches for several years. They find after studying nine storms and two hurricanes that Outer Cape Cod beaches can be cut back vertically as much as 9 feet and over 520 cubic feet of material can be removed during one storm tide.[1] Because of the strong littoral currents moving the eroded material north to the Cape Cod spit and because of the steep gradient of the beach and foreshore this beach can be very dangerous to bathers when strong winds and large waves occur.

The beaches found in other sections of the study site are not as large or as well developed. The beach bordering Cape Cod Bay is narrow where backed by cliffs. Where spits and bars occur the beaches are wider and less steep. Erosion is also a problem in this region but coastal retreat is not as great as on the Atlantic side.

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[1] J.M. Zeigler, C.R. Hayes and S.D. Tuttle: "Beach Changes During Storms on Outer Cape Cod, Mass." Journal of Geology, Vol. 67, No. 3, 1959, pp. 318-336.

Materials within the study site include coarse, unstratified, glacially deposited gravels and clays on the uplands. These deposits are covered with a thin veneer of silt and sand on the surface. Soft muds and clays are found in the bays and marshes, and medium grained sands cover the beaches. Mayo Beach near the town of Wellfleet is an example of a harbor beach with fine sands and clays.

Vegetation consists predominantly of pines and oaks. In places where the trees are exposed to high winds and storms, the trees are stunted. Marsh grass is found around the edges of the bays and in the tidal lagoons. Dune grasses help hold the sand on the Cape Cod Bay side of the coast but has difficulty in holding sand on the steep slopes on the ocean side of the cape.

Storm hazard. The Wellfleet area includes part of the exposed coastline of outer Cape Cod and so the storm frequency is high. Only moderate amounts of damage occur because the high morainic cliffs enable all waterfront property to be located well beyond the reach of storm waves. Waterfront property in the village of Wellfleet itself may be flooded but it faces onto the relatively sheltered Cape Cod Bay.

Two-and three-day "northeasters" are the most severe storms hitting the area. Hurricanes are infrequent and cause negligible damage. The northeasters are so frequent, however, that the number of storms recorded in the vicinity of Wellfleet is higher than at any other study site, except Dennis, also on Cape Cod.

The area in the Wellfleet region subject to coastal flooding is not large. However, Crane's map of coastal flooding in Barnstable County shows the town of Wellfleet as a major damage area and several marsh areas bordering Wellfleet harbor as subject to probable minor damage.[1] Most of the upland is well above the 20-foot contour.

The town of Wellfleet has been inundated when high tides and severe storms coincide. But because of its protected location, the inundation is not accompanied by storm waves or sudden tidal surges. Flooding of cellars is the worst damage from any of the storms, and in most cases, wind does much more damage than the sea. The United States Weather Bureau's storm surge map does not depict the Wellfleet study site as a region subject to severe storm surges.[2]

The flooding of the tidal marshes around Wellfleet Harbor may cover roads leading to rocky points but few structures receive damage. On the ocean side wind damage to structures is more severe than cliff erosion. Cliff erosion is such a slow process that most land owners can make adjustments well ahead of cliff removal.

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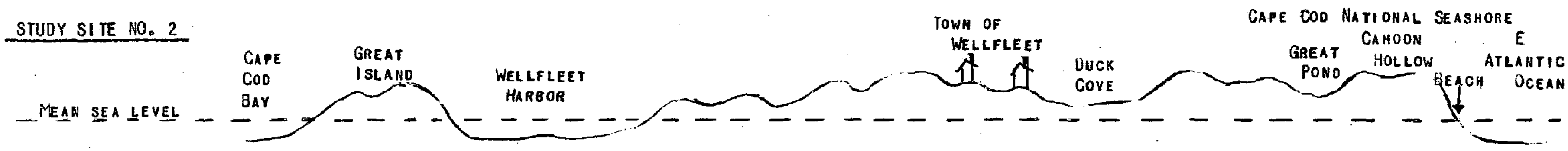
[1] Donald A. Crane: "Coastal Flooding in Barnstable County, Cape Cod, Massachusetts," Massachusetts Water Resources Commission, Bulletin W.R. No. 2, 500-4-63-935311, March 1963, Table I, p. 8.

[2] U.S. Department of Commerce, Weather Bureau, Storm Surge Warning Map. No. 5, Aug. 1962.



	A	D	A	B, C, D	D	B	D	A
Zone	Below mean high tide	Above 20 feet	Below mean high tide	Mean high tide to above 20 feet	Above the 20-foot contour	Mean high tide to 10 feet	Above the 20-foot contour	Below mean high tide
Geomorphic Type	Beach and cliffs	Glacial till	Tidal marsh unfilled	Low hills with small valleys	Rolling hills up to 150 feet covered with glacial till	Tidal marsh	Rolling morainic hills up to 150 feet above sea level. Large ponds	Steep 50-foot cliffs and beach
Type of Hazard	Erosion of beach cliffs in severe storms	No flood hazard	High water backs far up into the marsh areas during storms	Low areas in zone B subject to some flooding	No flood hazard	Flooding of low areas	No flood hazard	Immediate beach and cliffs subject to damage
Degree of Hazard	Moderate beach hazard	None	Some hazard from flooding	Only minor	None	Minor	None	Severe
Structures	None	Very few	Few	Few	Town of Wellfleet	None	Only a few summer homes near cliffs	None
Adjustments	Few		Few		Few	Few		

Figure 2-2. Diagrammatic cross section, Wellfleet, Massachusetts

Because of the sparsity of settlement along much of the coast in the Wellfleet area, it was difficult to establish a flood of record for the whole study site. A Corps of Engineers report in 1960[1] lists mean and spring tide maximums from 10 to 11.6 feet above mean low water for the ocean side of the Cape, while the Massachusetts Water Resource Commission Report[2] lists 14.5 feet above mean low water as the highest elevation of flooding. This maximum tide was observed in the 1938 hurricane. Field interviews indicated that 14.5 feet is a close estimate.

Settlement history.[3] In 1644, an exploration party was sent from Plymouth Colony to determine settlement possibilities on the Outer Cape. It was reported that it was not productive land and could support only 20 or 25 families. Otherwise, they felt that the area offered no possibilities for future expansion. Nevertheless, a number of settlers entered the area and settled on the more attractive farming sites. These early settlements were concentrated on the upland area of Chequesset Neck and at the head of Duck Creek.

By 1722, the population of this area had expanded sufficiently for Billingsgate, later to become Wellfleet, to be set off as a separate parish. Despite initial settlement for agricultural purposes, the population quickly turned to the abundance of fish in Wellfleet Harbor for its livelihood and the derivation of the name Billingsgate for the town stems from the famous Billingsgate fish market in London.

Throughout the first half of the 18th century, no village center evolved in the town of Wellfleet. Rather, settlement in the town remained in self-sufficient units on homesteads scattered along early roadways. Whaling and the fishing industry were the only cash-producing ventures of the period -- some 20 to 30 whaling vessels being based here and nearly all men of the town derived some income from the industry. Yet the economy was firm enough to support a population increase of from 928 people in 1764 to 1235 in 1775.

This population now began to locate in the chief areas of the town -- along the waterfront in response to maritime activity and along the old King's Highway. In addition to these major population concentrations, smaller nodes, numbering perhaps 20 to 30 families, were found in Billingsgate Island, Duck Creek, Griffith's Island and Bound Brook Island. These population localizations were in response to the fine harbors this area then possessed.

Throughout the first half of the 1800's, only rough roads connected settlements and the sea remained the chief means of travel. The King's Highway was the only major road, and early commercial establishments grew up along this route servicing travelers.

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1 Mass. Beach Erosion Control Study: "Shore of Cape Cod between the Cape Cod Canal and Race Point, Provincetown," Corps of Engineers, H. D. #404.

2 Crane, op. cit., p. 3.

3 Based on field party notes assembled from various locally available sources.

The early 1800's were years of greatly increasing industry in Wellfleet. During this period, the salt industry grew rapidly, largely because Wellfleet had acres of tidal marshland on which to locate the works and a ready market in the local fishing industry which needed the salt to cure its catches. In 1837, 39 salt works were in operation, producing a total of 18,000 bushels per year. After 1850, however, the industry declined with the development of salt springs in New York and the lifting of the duties on imported salt.

The prosperity of this period must be attributed in large part to the fishing industry, which grew steadily and reached its zenith in the second half of the 19th century. In 1837, there were 39 Wellfleet boats and 496 men employed in fishing, mostly for cod and mackerel. These boats required repairs and supplies, and the men who built and ran the wharves prospered in proportion to the fishermen.

Coincidental with the growth of commercial fishing was the depopulation of the island settlements and the centralization of the town around the Duck Creek area. The former harbors of these islands were fast silting up and by about 1830 most of the fishermen who used them had moved their vessels and homes to deeper water of Duck Creek. As Duck Creek became the principal harbor, the great wharves began to appear. Central Wharf, built in 1863 was 300 feet long and did a thriving business. Last of the great wharves, Mercentile Wharf, was erected in 1870, while even Blockfish Creek, harbor of South Wellfleet, had its own wharf where as many as 100 ships berthed. This general maritime prosperity was reflected in a series of small secondary and tertiary establishments which grew up along Commercial Street, the nucleus of the village.

The Civil War indirectly affected the Wellfleet area. Technological changes during the conflict led to the displacement of the small-boat type of commercial fishing carried on in Wellfleet. Metal-hulled ships and steam power made possible longer voyages and faster delivery to market. In addition, local fishing grounds were being depleted. By 1870, the handwriting was on the wall. By 1890, the number of boats rotting ashore was greater than the number in the water. This led to a decline in population in the area -- a trend which was not reversed until very recently.

The conversion of the Wellfleet economy from fishing to tourism began with the events near the turn of the century. The first occurred when a wealthy resident of Wellfleet, Captain Baker, purchased Mercentile Wharf and spent $100,000 converting the old wharf buildings into the elegant Chequesset Inn. Advertising drew clientele from as far away as the Middle West and Wellfleet soon became known as a "summer resort" as well as a fishing village. Captain Baker also organized the Wellfleet Yacht Club which helped to promote Wellfleet as a summer resort.

A second factor in the introduction of tourism in Wellfleet was the construction of the Fall River and Old Colony Railroad. It eventually captured virtually all the freight business and opened up Wellfleet to the outside world. In Wellfleet, the greatest single blow struck against maritime activity was the construction of the railroad dike across the mouth of Duck Creek, sealing off the upper reaches of the Creek to ships of deep draft.

Old-timers recall that, in the first 10 or 12 years of this century, while summer people were an accepted phenomenon, they were still so few in number as to be a novelty. The growth of tourism is, of course, closely associated with the growth of automobile use. Because of the decline of fishing and local industries, there were a large number of vacant properties in town and so summer people began to buy permanent homes. In fact, native owners thought that they were selling white elephants to these "city folk" at ridiculously high prices. Wellfleet natives also supplemented their income by renting rooms and cottages and by 1920, Wellfleet was well on its way to becoming a "summer town." By 1952, the year of first photo coverage, the village found its traditional hybrid settlement pattern largely unchanged, but with functional changes in the use of the buildings. Retail units in the village center catered to the tourist trade while former residential homes supplemented their income by serving as guest or tourist homes. The village as a whole, however, retains its traditional settlement pattern and has not experienced rapid commercialization or permanent population expansion.

Land use changes. There has been a substantial increase in the number of structures in the 25-year period from 1938 to 1963. Single family residences (mostly summer cottages) have increased from 143 to 307. Most of them are well above the flood hazard zone. The most significant increase in damage potential is in the growth of commercial structures (mainly motels and guest houses) in Zone C within the reach of extremely high storm waters. A new town wharf has also been constructed at Shirtail Point. A map of land use is shown in the overlays to figures 2, 2a. Recorded changes of land use are given in table 2-2.

Adjustments to hazard. The perception of storm hazard in Wellfleet is not highly developed. Public adjustments are limited to a breakwater at the mouth of the inner Wellfleet Harbor and beachgrass plantings along the cliffs on the eastern shore. There are very few private adjustments. These include the construction of one bulkhead. There is greater concern about wind damage than water damage and precautions are taken to make structures able to withstand high winds.

The relatively low level of knowledge of storm hazard is probably due to the relatively small damage potential resulting from the favorable topographic conditions of the area.

Future development. Recently much of Wellfleet (75 percent of its area) has been taken over by the Federal Government as part of the Cape Cod National Seashore. Although the establishment of the Seashore had little effect by the summer of 1963, it is expected that the National Seashore will eventually have a big impact upon service industries in the area. Many more motels and restaurants and other tourist services are likely to be built. In addition there are plans for developing the National Seashore itself by the provision of trails, parking facilities, exhibits, and bathing facilities. This is not likely to create significant amounts of new damage potential, especially since most of the developments are to be on the higher Atlantic side of the peninsula.

The future development of the National Seashore will result in increasing the accessibility to Wellfleet since plans are now in motion to widen existing 2- and 3-lane

Table 2-2

Wellfleet, Massachusetts

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures 1938	No. Structures 1963	No. Structures % change	No. Acres 1938	No. Acres 1963	No. Acres % change
A	5b Recreational	0	0	0	47	49	+4
	7 Agricultural	0	0	0	76	0	na[2]
	8 Undeveloped	0	0	0	236	310	+31
Tidal	Total	1	2	+100	377	375	0
B	5b Recreational	0	0	0	14	18	+29
	6a Residential	9	13	+44	2	8	+300
	8 Undeveloped	0	0	0	128	122	-5
Tidal-10'	Total	9	15	+67	155	155	0
C	2 Commercial	6	36	+500	3	7	+133
	5b Recreational	0	0	0	15	12	-20
	6a Residential	68	87	+28	82	102	+24
	8 Undeveloped	0	0	0	270	250	-7
10'-20'	Total	74	123	+66	386	390	+1
D	2 Commercial	3	57	+1800	19	25	+32
	6a Residential	65	205	+215	62	192	+210
	8 Undeveloped	0	0	0	1327	1190	-10
> 20'	Total	68	262	+285	1410	1408	0
F	2 Commercial	0	13	na	1	3	+300
	6a Residential	12	14	+17	2	4	+200
	8 Undeveloped	0	0	0	252	248	-1
Flooded	Total	12	27	+125	255	255	0
All Zones	2 Commercial	9	95	+956	23	33	+44
	3 Public	0	0	0	2	1	-50
	4 Recreational	0	0	0	18	18	0
	5a Recreational	0	0	0	30	21	-23
	5b Recreational	0	0	0	70	79	+13
	6a Residential	143	307	+115	148	304	+105
	7 Agricultural	0	0	0	76	0	na
	8 Undeveloped	0	0	0	1961	1872	-4
	Total	152	402	+163	2328	2328	0

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] na -- Calculation not appropriate.

roads into 6-lane super highways. The increase in the number of visits to the area is likely to disrupt the cloistered character of Wellfleet and move it very rapidly toward a resemblance of the Lower Cape.

The potential for recreational development is greatest in the Cape Cod National Seashore area. On the bay side much of the land is in marshes and the existing town beaches are used to capacity at the height of the season.

Nevertheless the location of the village of Wellfleet immediately adjacent to the National Seashore seems certain to involve it in major changes.

Wellfleet is an example of a village type of coastal development that has long had some small tourist industry. In the future it is likely to experience rapid conversion to a summer shore type of development as the National Seashore is developed. Future developments are not likely to result in a large increase of damage potential largely due to the favorable topographic features of the area and the fact that much low lying development faces onto the relatively sheltered Cape Cod Bay.

3. Villas, New Jersey[1]

Villas is an expanded village-type coastal development. Its low income houses are arranged along grid-pattern streets fronting onto Delaware Bay on the western side of the Cape May peninsula. This smallest of the study sites includes 1.2 miles of coastline and extends in a strip .5 mile wide. The total area is 222 acres. (See figure 3 in the appendix.)

Physiography. The entire area of Villas is comprised of two basic landform types. (See cross section figure 2-3.) A nearly flat plain averaging between 10 and 20 feet above mean sea level makes up 62 percent of the site. This plain is composed of coarse Pleistocene gravels with a thin silica sand veneer on the surface. Mixed oaks and pines along with herbaceous plants are the predominant vegetation.

The remaining 38 percent of the study site is marshland. Here silts and clays are covered with high elephant grasses and herbaceous plants. The southern and northern parts of this small area fringe on the housing development at Villas, to the south, and Del Haven, to the north. The central part is the marshland which is crisscrossed with channels for control of mosquito breeding. A small creek, Fishing Creek, flows west through the area to Delaware Bay.

The coastline at Villas is non-cliffed and regular in shape. The beach zone is very narrow, less than 100 feet wide. It is made up of coarse gravels, silts, and sands. Offshore the sediments become finer on the gentle slope that leads into Delaware Bay.

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[1] Field work by Robert Arnold and Richard Hecock. We are indebted to the following person who supplied information; Mr. James Byington.

This coast is not a popular resort area for tourists, but Miami Beach and Sunray Beaches are used by local residents. Backing the beach is a narrow area of low 4-to 5-foot high sand dunes covered mostly with American beach grass.

Storm hazard. Villas has a relatively low frequency of damaging storms. Large waves and tidal surges do not form in the sheltered Delaware Bay, although strong west winds sometimes pile water up against the shore and cause beach erosion and slow undermining of waterfront buildings. Wind damage is caused both by hurricanes and "northeasters", but wave damage is rare.

The flood of record for this stretch of the Delaware Bay coastline is about 9 feet above mean sea level. Since all of the study site, except the larger dunes near the coast, is below 9 feet, flooding is a potential danger although it would be from relatively still water without strong wave action.

Settlement history. Though the very earliest development in Cape May occurred not far from present day Villas, it appears that there was little activity in the Villas area until sometime in the late 1800's. A map of Cape May County in 1872 shows a few scattered houses which appear to be farm houses. Probably fishing, oystering and clamming were carried on at that time also.

Modern development in the Villas area and more specifically in the study area did not commence until the late 1920's when a man named Millman bought a large tract of land and began building houses suitable for seasonal and permanent residences. Villas is today largely the result of Millman efforts.

Land use changes: There has been a steady growth of single family residences in Villas over the past 8 years. Their number has increased from 221 in 1956 to 292 in 1963. The new developments are largely below the ten-foot contour and could be flooded by exceptionally high water. The pattern of land use is shown in the overlay to figure 3 (appendix). Recorded changes of land use are given in table 2-3.

Adjustments to Hazard. The level of concern about storm hazards in Villas is very low. A few people are affected by beach erosion and have privately made adjustments by construction of bulkheads or rip-rap. Public measures include the construction of several jetties into Delaware Bay.[1] A few dunes along the shoreline have been removed to make way for beach front cottages. In addition sluices have been built to keep salt water out of the marshland areas.

Future development. The character of Villas has not changed significantly in recent decades and will probably continue for the foreseeable future as a relatively low income summer resort and retirement area. The fishing has changed from a commercial venture to sport fishing for summer tourists who are able to enjoy a low cost vacation at a rather poor quality beach.

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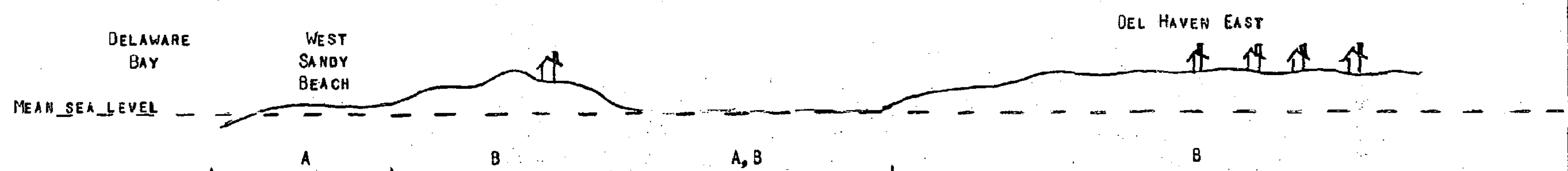
[1] U.S. Army Corps of Engineers: New Jersey Coast of Delaware Bay from Cape May Canal to Maurice River, Beach Erosion Control Study, 87th Congress, 1st Session, House Doc. No. 196, 1961, pp. 20-28.

STUDY SITE NO. 3



ZONE	BELOW MEAN HIGH TIDE	BETWEEN MEAN HIGH TIDE AND 10 FEET	BELOW MEAN HIGH TIDE TO 10 FEET	BETWEEN MEAN HIGH TIDE AND 10-FOOT CONTOUR
GEOMORPHIC TYPE	BEACH	SAND DUNES	BRACKISH MARSH - SILTS AND CLAYS	FLAT TERRACE LAND - SANDS AND GRAVELS
TYPE OF HAZARD	EROSION OF BEACH DURING SEVERE STORMS	MINOR EROSION TO THE LOW DUNES	SALT WATER INUNDATION DURING SEVERE STORMS - LITTLE FLOODING	NO FLOOD HAZARD
DEGREE OF HAZARD	MODERATE BEACH HAZARD	MINOR	ONLY MINOR HAZARD FROM FLOODING	NONE
STRUCTURES	FEW	VERY FEW	FEW	SMALL HOUSING DEVELOPMENTS
ADJUSTMENTS	ONLY VERY MINOR	FEW	MINOR	FEW

FIGURE 2-3 DIAGRAMMATIC CROSS SECTION, VILLAS, NEW JERSEY

Table 2-3

Villas, New Jersey

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures 1956	No. Structures 1963	No. Structures % change	No. Acres 1956	No. Acres 1963	No. Acres % change
A	8 Undeveloped	0	0	0	56	56	0
Tidal	Total	0	0	0	56	56	0
B	2 Commercial	16	16	0	-	-	
	6a Residential	206	269	+31	75	84	+12
	8 Undeveloped	0	0	0	88	79	-10
Tidal-10'	Total	222	285	+28	163	163	0
C	2 Commercial	7	8	+14	-	-	
	6a Residential	15	23	+53	2	3	+50
	8 Undeveloped	0	0	0	1	0	na[2]
10'-20'	Total	22	31	+41	3	3	0
D	None in study area						
F	8 Undeveloped	0	0	0	87	87	0
Flooded	Total	0	0	0	87	87	0
All Zones	2 Commercial	23	24	+4	-	-	
	6a Residential	221	292	+32	77	87	+13
	8 Undeveloped	0	0	0	145	135	-7
	Total	244	316	+30	222	222	0

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] na -- Calculation not appropriate.

There remains a large amount of undeveloped marshland in the area. The recreational amenities are not sufficiently attractive to encourage rapid development, but a slow expansion into the marshland seems probable, with an associated slow increase in water damage potential.

4. Chincoteague, Virginia[1]

The fourth and final example of village shore development is the village of Chincoteague on the island of the same name. The study site includes almost all of Chincoteague Island. (See figure 4 in the appendix.) This study site lies immediately adjacent to Assateague, the subject of case study number 15.

Physiography. This study site is similar in physiographic characteristics to the Assateague site. Both are low sandy regions which are subject to changes in their shape and size as tidal channels and offshore currents move the unconsolidated sands and clays from place to place.

Chincoteague Island consists largely of sand dune ridges, sand plains, and tidal marshes. (See cross section, figure 2-4) The ridges and swales are much older than those on Assateague Island and are worn down. At least 20 of these accretion ridges can be counted on aerial photographs. Each ridge represents low dunes formed behind a prograding coast and beach. What was once a barrier bar, similar to Assateague, has become an island by the accretion of tidal channels in the lagoon which have cut across the northern part of the island.

No part of Chincoteague is 10 feet above mean sea level. Most of the island (about 34 percent) consists of tidal marshland. The town and residential areas of Chincoteague are located along the slightly higher accretion ridges, which make up approximately 62 percent of the island. Sand on the ridges and clay in the swales are the only materials found on the island. Soils are poorly developed, but a few vegetable crops are grown.

Chincoteague has few sandy beaches. Approximately 4 percent of the study site has a sandy coastline but no wide beaches. The irregular shoreline consists mostly of marsh and shifting tidal channels. In the south-eastern part of the island these channels are presently eroding the land. Pines and oaks are the principal trees found on the ridges with mixed grasses and shrubs in the low areas.

Storm hazard. Storm frequency at Chincoteague is relatively low, although heavy damage has resulted from storms in the recent past.

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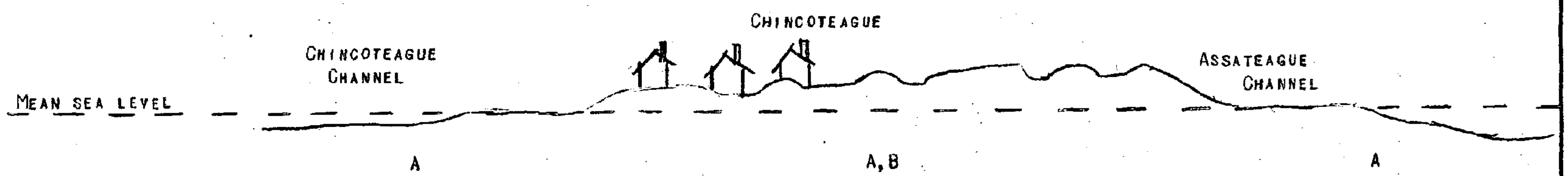
[1] Field work by Robert Arnold and Richard Hecock. We are indebted to the following persons who supplied information: Mr. R.N. Reed, Mr. Roy Tolbert, Mr. Roy Twilley, W.N. Steelman, Mr. Charles Noble, Lt. Cmdr. H.H. Istok, and Mr. Jeffries.

STUDY SITE NO. 4



ZONE	BELOW MEAN HIGH TIDE	LOW AREAS BELOW MEAN HIGH TIDE - OTHER AREAS LESS THAN 10 FEET	BELOW MEAN HIGH TIDE
GEOMORPHIC TYPE	TIDAL FLATS, MARSHES AND CHANNELS WITH SILTS AND CLAYS	OLD BARRIER ISLAND WITH NUMEROUS SAND RIDGES. SILTS AND CLAYS IN THE SWALES	TIDAL FLATS, MARSHES AND CHANNELS WITH SILTS AND CLAYS
TYPE OF HAZARD	TIDAL INUNDATION AND CHANNEL EROSION	FLOODING AND CHANNEL EROSION	TIDAL INUNDATION AND CHANNEL EROSION
DEGREE OF HAZARD	MINOR EROSION BUT SEVERE FLOODING	SEVERE FLOODING	MINOR EROSION BUT SEVERE FLOODING
STRUCTURES	FEW	MANY	FEW
ADJUSTMENTS	MODERATE	MINOR ADJUSTMENTS TO CHECK EROSION AND FLOODING, EARTH WALLS, ELEVATION OF STRUCTURES	MODERATE

FIGURE 2-4. DIAGRAMMATIC CROSS SECTION, CHINCOTEAGUE, VIRGINIA

Both severe flooding and shore erosion occur at Chincoteague. A record flood of 10 feet above mean sea level was estimated from field interviews. Since no part of the island reaches this height, the area is entirely covered with storm water from time to time. This has occurred both during hurricanes and during other storms such as that of March 6-7, 1962.[1] Flooding takes place mainly from the bay side because the island is protected from the ocean waves by Assateague barrier bar.

Wind damage from hurricanes is not severe to structures on Chincoteague because the town is on the landward side of the island and is protected by forest cover.

In the storm of March 1962 practically the whole community was inundated by water and high waves. Only one life was lost but much livestock including over 350,000 chickens and about 100 horses and ponies were drowned.

About 2,000 inhabitants were evacuated to a NASA installation (formerly the Chincoteague Naval Air Station) near Temperanceville for as much as four or five days. The Red Cross established facilities for providing food and clothing. The U.S. Navy furnished helicopters and the U.S. Coast Guard provided helicopters and DUKW's for evacuating people from the island. The National Guard and Coast Guard prevented looting. The Corps of Engineers and State Highway Department assisted in clearing and removing debris. The Corps also returned many stranded boats from streets to the adjoining waters.

All streets were flooded with from one to five feet of water but sustained relatively minor injury. The bridge approaches to the one highway were battered by the storm and had to be repaired. There was major damage to docks. Fishing vessels ranging in size from small rowboats up to 60-foot craft were washed ashore.

The water supply, power, and telephone service was disrupted. Radio was the only means of communication available for two or three days. Approximately 60 business establishments and 1,226 houses were flooded by water rising from one inch to four feet into the buildings. Houses along the Chinocoteague Bay waterfront on the west side of the island were demolished or received major damage from wave action in Chincoteague Bay, whereas those on the center and east side of the island sustained stillwater damage without wave action.

The adjacent clam beds and oyster grounds were covered with silt and mud by the storm and were therefore seriously damaged. Since most of the inhabitants are fishermen, there will be a material loss of wages over a considerable period of time.

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[1] U.S. Army Corps of Engineers, The March 1962 Storm Along the Coast of Maryland, U.S. Army Engineer District, Baltimore, Maryland (November 1962), pp. 7-9.

The following table summarizes the loss to the community:

Damage from March 1962 Storm at Chincoteague

Damage To	Estimated Loss
Residences, stores, and personal property	$ 5,000,000
Livestock	200,000
Piers, bulkheads, and other shore structures	100,000
Vessels	1,000,000
Oyster ground, clam beds, etc.	800,000
Total damage	$ 7,100,000

Settlement history.[1] Both Assateague and Chincoteague islands were inhabited in the early 16th century by the Chincoteague Indians. The first white inhabitants, 30 settlers from the Virginia Company, were brought to Chincoteague in 1671.

From the earliest settlement, the population of the island has been concerned largely with extracting food from the sea. This has continued to the present and is now the mainstay of the economy of Chincoteague. Subsistence farming was carried on during colonial times. There is no record of other farming developments until after the bridge to the mainland was opened to Chincoteague in 1922.

A portion of the island of Chincoteague was incorporated as the Town of Chincoteague in 1908. The population had grown sufficiently so that by the time the bridge to the mainland was opened, there were approximately 200 persons living on the island. There were a large number of fishing families living on Assateague after 1900, but when access to Chincoteague and their fishing grounds was legally closed by a private property owner, these families gradually began to move back to Chincoteague.

Peak population hit 5,500 at the time of the closing of the Naval Air Station and is now down to 3,800. A substantial agricultural venture began on Chincoteague in the mid-20's. Chicken raising went into full swing in the 1930's and hit its peak in 1945-46 when one-third of island employment was in the chicken industry. There followed a slow decline and a resultant change from individual enterprise to corporate financed business. The business is, at present, fairly stable.

Land use changes. There has been little change in this study area from the date of the first air photo coverage available (1949) to the present. Results of structure and

[1] Based on field party notes assembled from various locally available sources.

acreage counts by hazard zones are given in table 2-4. A map of land use is shown in the overlay to figure 4 (appendix.)

The prosperity of Chincoteague was adversely affected when the U. S. Naval Air Base on the nearby mainland was closed down in 1957-58. The population of the island community dropped sharply and about 200 houses were left vacant. With the establishment of a NASA administrative and technical unit at the former Navy Base, some new jobs have been created and a welcome boost has been given to the local economy. Many of the houses vacated in 1958 have been converted for tourist use, and other vacant houses have been rented.

There has been little over-all land use change since 1949. One new school has been added, and two small housing developments constructed. The larger of these has 18 houses.

Adjustments to hazard. There is relatively high degree of awareness of storm hazard in Chincoteague. Many of the residents have lived in the village all their lives and know of the hazard from experience. Nevertheless the range of adjustments and their frequency of adoption is smaller than at Point Judith where heavy damage has also occurred.

Private adjustments include the construction of a wall around one house; the raising of several houses on piles; the construction of a crate to protect pumps, and the raising of merchandise and furnishings onto the second floor. Evacuation is a precaution taken by some residents when storm warnings are issued. In the March 1962 storm 65 percent of the population left for the mainland. However, a number of residents, especially the older people, remained throughout the flood.

One consequence of the March 1962 storm is that several new commercial establishments have been built along Main Street to replace buildings damaged or destroyed.

Future development. The study area has changed little in recent years, and prospects for growth have not been encouraged by the closing of the Naval Base or by the storm of March, 1962.

The seafood industry is highly dependent on market conditions, and at best is unlikely to experience more than a slow growth. It is not yet clear what the full impact of the 1962 storm will be on the oyster industry, but the oyster beds suffered severe damage and recovery may be slow.

The main hope of the area for future growth and development is the tourist industry. There have been few signs of growing tourist interest, but increased accessibility and the density of coastal developments further north suggest that the "wave" of heavy tourist activity may soon reach Chincoteague. The construction of the bridge-tunnel across the mouth of the Chesapeake Bay from Norfolk to Cape Charles, and the opening of a ferry service across the Delaware Bay from Cape May, N. J., to Lewes,

Table 2-4

Chincoteague-Assateague, Virginia

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures 1942-43	1949	% change	1963	% change	No. Acres 1942-43	1949	% change	1963	% change
A	8 Undeveloped	0	0	0	0	0	1697	1694	0	1690	0
Tidal	Total	0	3	na[2]	3	0	1697	1697	0	1697	0
B	1 Industrial	30	30	0	33	+10	3	3	0	3	0
	2 Commercial	143	149	+4	160	+7	25	25	0	25	0
	6a Residential	796	1174	+48	1231	+5	464	648	+40	696	+7
	7 Agricultural	200	120	-40	121	+1	230	46	-80	46	0
	8 Undeveloped	0	0	0	0	0	1185	1176	-1	1083	-8
Tidal-10'	Total	1178	1506	+28	1578	+5	1907	1907	0	1907	0
C D	None in study area										
F	1 Industrial	30	30	0	33	+10	3	3	0	5	+67
	2 Commercial	143	149	+4	160	+7	25	25	0	25	0
	3 Public	8	22	+175	22	0	0	0	0	0	0
	4 Recreational	0	0	0	0	0	0	9	na	34	+278
	5a Recreational	0	11	na	11	0	0	0	0	20	+1900
	5b Recreational	0	1	na	1	0	0	0	0	0	0
	6a Residential	796	1175	+48	1232	+5	464	648	+40	698	+8
	6b Residential	1	1	0	1	0	0	0	0	0	0
	7 Agricultural	200	120	-40	121	+1	230	49	-79	49	0
	8 Undeveloped	0	0	0	0	0	2882	2870	0	2773	-3
Flooded	Total	1178	1509	+28	1581	+5	3604	3604	0	3604	0

Note: Zone F includes all the study area; therefore, no separate figures are given for the total area. This table includes data on both Chincoteague and Assateague (site number 15).

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] na -- Calculation not appropriate.

Del., will improve the accessibility of the Delmarva Peninsula. With these new developments, Chincoteague will become much more accessible.

The conversion of a part of the National Wildlife Refuge on Assateague Island to a public beach (see case study number 15) and the construction of the Chincoteague-Assateague bridge mark the beginning of a new era for the village of Chincoteague. Formerly visitors had no ready access to a good beach, but with the facility now available the number of tourists may be expected to increase.

There is also a proposal to develop a National Seashore on Assateague Island. When this venture materializes the northern and southern parts of Assateague will be connected with a road thereby making Chincoteague an important access point for visitors.[1] In any case town officials, citizens, and merchants for the most part are convinced that the tourist industry has an important role in Chincoteague's future. A harbor of refuge has already been established. There is talk of a beach on the southeast corner of the island. There are several marinas on the island now. Advertisements of Chincoteague's attractions are appearing in Philadelphia, Baltimore, Richmond, and New York papers.

On the other hand, Chincoteague has little to offer in the way of spectacular attractions such as boardwalks, ferris wheels, and night clubs. This is no doubt an attraction to an important segment of potential recreational visitors. Furthermore, since Chincoteague itself has little to offer in the way of suitable beach sites, it is dependent on Assateague as an attractive force.

The Chincoteague-Assateague area is an example of a village shore area poised and ready for rapid expansion when the "wave" of coastal resort development reaches this far south. It has many attractive characteristics as a quiet place to which people can escape but it is in a low lying and hazardous area. There are no safe sites suitable for development. It might therefore be thought desirable to preserve the village atmosphere and wildlife amenities of the area for their own sake. Development must necessarily result in the creation of more storm damage potential in an area that is very difficult to protect. The pressures for development are such, however, that there is no sign of any resistance to rapid development of cottages and motels when the time becomes opportune. The Chincoteague-Assateague area will need outside help if its present attractive features are to be perserved and if it is not to become a new site for the further creation of storm damage potential.

Development has not yet come to Chincoteague. It is in such places that great opportunity still exists for the planned preservation of coastal amenities without involving the nation in costly protection works or heavy flood losses.

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[1] As of June 11, 1965, the Senate Interior subcommittee issued a favorable report to the parent committee for the establishment of the Assateague Island National Seashore that included an amendment to provide for the disputed road linking the two parts of the island.

The Urban Shore

5. Lynn-Nahant, Massachusetts[1]

Lynn is an industrial complex within the Boston metropolitan area. Little Nahant is a residential section built on a bedrock island. This island is connected to the mainland by a long sand bar or spit called a tombolo. The study area includes 3.1 miles of Massachusetts coastline just north of Boston. The area selected extends inland for less than half a mile from Lynn Harbor, and includes sections of Revere Beach, the harbor itself, and yacht clubs and pocket beaches along the shoreline of the city of Lynn. Also included are Little Nahant and the tombolo which connects it to the mainland usually referred to as Lynn Beach. (See figure 5 in the appendix.) The total area is 596 acres.

Physiography. About one-quarter of the site (26 percent) consists of barrier sand bars. The southern section of the study site includes the northern one-half mile of Revere Beach. This beach is a barrier bar, two miles in total length, which has grown north from the rocky headlands at Beachmont. The growth of this bar has nearly closed off a series of tidal marshes and small rivers on the inner side.

The northern section of Revere Beach is narrow and has a thin veneer of sand that at times is removed, exposing the soft muds and clays of Lynn Harbor. Although protected by Nahant from northeasters, the beach does suffer erosion when high winds and storm waves come from the southeast. In the Point of Pines section of the bar, two sand ridges, less than 10 feet in elevation, are separated by a depression which runs down the center of the bar. This area is subject to flooding when water crosses the sand ridges.

A second barrier bar included within the study site is the tombolo which connects Little Nahant to the mainland. This gently curving bar is about one mile long and 100 feet wide. The beach on the east side is wide with a gentle gradient. This is a popular, "safe" beach because the gentle gradient modifies the large waves offshore before they spread out around Nahant Bay. However, the beach varies greatly in width because of the 9.2 foot tidal range. On the west side of the tombolo, no beach exists and a protective wall has been built with large stone blocks to help prevent the bar from being breached during storms. Also, mud flats are much more extensive in Lynn Harbor than in Nahant Bay. The tombolo which connects Little Nahant to the mainland is the largest of the complex tombolos which connect sections of Big Nahant to Little Nahant.

About 46 percent of the study site consists of artificial fill over former marsh area. This includes the industrial area of southeast Lynn, a United States Military Reservation, and the yacht clubs of Lynn Harbor. Another 8 percent is tidal marshland which is landward of Revere Beach bordering upon the Saugus and Pines Rivers.

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[1] Field work by Robert Arnold and Richard Hecock. We are indebted to the following persons who supplied information: Mr. Joseph Macaioni, Mr. William George, and Mr. William Barber.

The remaining 20 percent of the site includes the bedrock island of Little Nahant and a small section of bedrock mainland near Red Rock promontory. (See cross section, figure 2-5.) Little Nahant has an elevation of more than 80 feet above mean sea level while the mainland sections of Lynn average 10-20 feet high. A thin veneer of glacial till covers these two areas. The seaward facing cliffs of these two areas are under heavy wave attack. At the base of the cliffs, large boulders, which have fallen out of the till, remain in place forming a boulder strewn platform.

The materials that make up this study site consists of sand, with some gravel, along the beaches and bars and in Lynn Harbor. Silts and clays are found in the marshes. Bedrock underlies Little Nahant and the mainland, with a thin veneer of gravels and boulders on top. The man-made fill consists of miscellaneous materials, mainly gravels.

Vegetation is generally sparse because of the high density of structures and population in this area. Some marsh grass occurs along the Pines River. On the tombolo connecting Little Nahant with Lynn a few dunes have American dune grass. Mixed trees and herbaceous plants are found in the residential parts of Little Nahant and Lynn.

Storm hazard. Although storm frequency is relatively high at Lynn-Nahant the hazard is only of moderate dimensions. Hurricanes are rare events and the more frequent danger is from "northeasters". Water damage is more important than wind damage but neither are usually severe. The United States Weather Bureau's Storm Surge Warning Map[1] states that Revere Beach boulevard and the Lynn-Nahant causeway begin to be flooded when water reaches 8. 5 feet above mean sea level. When the causeway becomes flooded Little and Big Nahant are cut off from the mainland as water covers the beaches and the whole tombolo during severe storms.

The Corps of Engineers has established the flood of record at 12. 5 feet above mean sea level at Revere Beach and 13. 5 feet at Lynn Beach.[2] Field interviews set the flood of record around 10 feet, with a range of from 8 to 15 feet above mean sea level.

The 13. 5 feet at Lynn Beach appears to be the most accurately recorded flood to date, but with a tidal range of 9. 2 feet from mean low water to mean high water it is highly possible that a tidal surge could reach 15 feet above mean sea level. Although the flood of record for Lynn Harbor is 12. 5 feet, as against 13. 5 feet for Nahant Bay, strong east and southeast winds will cause piling up of water in Lynn Harbor with resulting danger to piers and yacht clubs at the head of the harbor.

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[1] U. S. Department of Commerce, Weather Bureau, Storm Surge Warning Map, No. 3, August, 1962.

[2] U. S. Army Corps of Engineers, Lynn-Nahant Beach, Mass. - Beach Erosion Control Study, 82nd Congress, 1st Session, House Doc. No. 134, 1951, pp. 14-17, and Revere Beach, Mass. - Beach Erosion Control Study, 82nd Congress, 1st Session, House Doc. No. 146, 1951, pp. 14-18.

Most of the filled-in area of Lynn is above the 9-foot contour, and the sea walls are now above 10 feet. Only very rarely would the lower part of the city become flooded. However, no structures in this area are able to have basements because of flooding.

Storms periodically flood property adjacent to the coast in Lynn and the inhabitants of Little Nahant are sometimes isolated from the mainland when the tombolo is over-topped.

Settlement history. Lynn was settled in 1629 and named in honor of King's Lynn in Norfolk county, England. At the time of settlement, tanning and shoemaking were established on a small scale. Tiny "back yard" shops increased in number until Lynn was supplying most of the footwear for Boston. In 1810, about one million pairs of shoes were manufactured in the town.

The factory system evolved in the mid-eighteen hundreds. Lynn was the leading shoemaker in the nation until the late 19th century. By 1915 it had dropped to third place. The city however had varied industries which enabled it to survive periods of change and economic instability.[1] Shoe factories and connected trades continued to predominate numerically. Today General Electric Company is a major employer in the city, whose population numbered in 1960, 94,478. Lynn serves as an industrial satellite community for the Boston Metropolitan area.

Nahant was settled in 1630, but the rocky island did not grow sufficiently to be incorporated until 1853. Nahant and Little Nahant were purchased from an Indian chief in 1730 by Thomas Dexter, a Lynn farmer. In 1802 a tavern called "Castle" was erected which catered to the sportsmen set. Due to the success of the venture and the establishment of steamboat service to Boston in 1817, Nahant began to develop rapidly as a symbol of Boston Society's idea of low-cost high living. The Saturday night dinners of the "Nahanters", noted mainly for their exclusiveness and penny-ante basis, ended during World War II when General Electric bought the Club as a recreational center for its employees.[2]

Land use changes. The pattern of land use in the area was well established by the date of the first photographic coverage in 1939. Changes have consisted largely of intensification of density of development. Residential areas established by 1939 have remained residential but the density of buildings has increased. Thus the number of single family residences was more than twice in 1963 what it was in 1939. The major exception to the pattern of continued trends is to be seen in the area bounded by Commercial St., Lynn Harbor, the Sagus River, and the railroad tracks. In 1939 this was largely vacant, an almost entirely undeveloped area. Since 1939 it has been developed into a high density industrialized area, bisected by a strip of ribbon development of various commercial activities. This area accounts for most of the industiral growth in the study site, but it is thought to be above the flood hazard zone.

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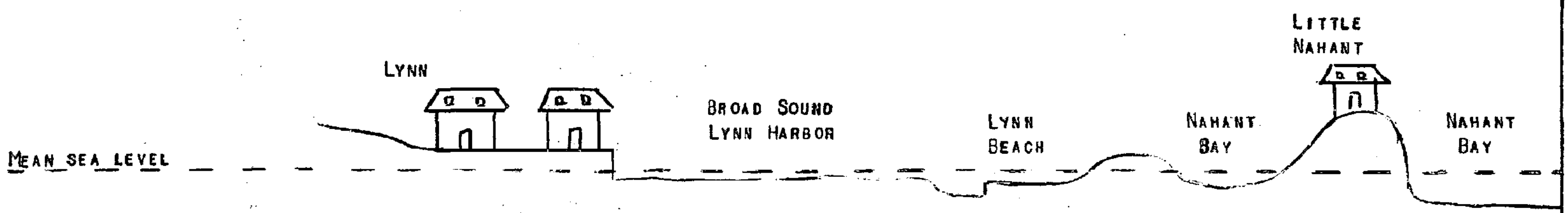
[1] Federal Writers' Project, Massachusetts, Boston: Houghton-Mifflin Co., 1937, p. 267.

[2] Cleveland Amory, The Proper Bostonians, New York: E. P. Dutton & Co., 1947, p. 198.

STUDY SITE NO. 5



	B, C	A	B	A	B, C, D	A
Zones	Above mean high tide	Below mean high tide	Above mean high tide, but below 10 feet	Below mean high tide	Above mean high tide to above 20 feet	Below mean high tide
Geomorphic Type	Rolling upland surface with fill in low area near the harbor	Very shallow bay except where dredged	Sand bar (tombolo)	Shallow bay	Bedrock island - some glacial till	Bay
Type of Hazard	Flooding in low areas	Tidal inundation - filling of bay with sand bars	Flooding and erosion	Erosion	High waves erosion	Erosion
Degree of Hazard	Minor	Minor	Severe	Moderate	Minor	Moderate
Structures	Many	Few	Few	None	Many	None
Adjustments	Sea walls and bulkheads around Lynn Harbor with some fill	Dredging to keep channels open	Sand and rock fill, dune protection	Few	Few	Few

Figure 2-5. Diagrammatic cross section, Lynn-Nahant, Massachusetts

The hazard zone is confined to only 35 acres out of a total of 596. On this 35 acres there has been a very small increase of single family residences from 118 to 124. A map of land use is shown in the overlay to figure 5 (appendix). Recorded land use changes are given in table 2-5.

Adjustments to hazard. Knowledge of storm hazards appears to be relatively smaller in Lynn-Nahant than in other coastal areas studied. This may be attributed in part to the lack of heavy storms in the past few years and to the small extent of area subject to flooding. It is also likely that dwellers on the urban shore are less aware of the hazards of nature than dwellers on the village shore or the summer shore.

Private adjustments include construction of a seawall and the use of sand bags and dikes. Local residents have also been active in promoting the idea of an off-shore seawall to break up the waves. The land reclaimed has been filled to levels above the maximum flood of record. Plans are also in existence for the evacuation of the seafront area during heavy storms.

Public adjustments include the construction of a reinforced concrete seawall 8 to 10 feet high along sections of Revere Beach. Work was in hand in 1963 to raise these to at least 10 feet. The causeway and rock rubble embankment along the tombolo to Little Nahant have been raised to 8 feet above mean sea level. Man-made fill to about 9 feet above mean sea level has been placed in the Lynn Harbor section for industrial and military sites.

To protect Lynn an extensive seawall over 10 feet in height has been built along the filled section and along the small pocket coves near Red Rock promontory.

Proposed projects include making Lynn Harbor a harbor of refuge and the filling in of 5-1/2 acres of lowland at Revere to a height of 10 feet. New marinas and recreational areas are proposed as fill is being added to the marsh and mud flats bordering on Lynn and Revere. Wherever possible one or two feet of fill are being added to all low areas.

Future development. Land use changes in the near future are likely to be confined to the further intensification of development and the use of the only remaining tract of undeveloped land by the Lynn Gas and Electric Co. There are plans for urban renewal and redevelopment in the area but it is difficult to estimate how soon these are likely to be implemented.

There does not appear to be much potential for further recreation development in the area unless urban renewal schemes are adopted.

Lynn-Nahant is a complex and diversified area where the intensity of development is high and the awareness of storm hazard is relatively low. Little further damage potential is likely to be created and the future character of the area depends largely on the coming of urban renewal.

Table 2-5

Lynn-Nahant, Massachusetts

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures 1939	No. Structures 1963	No. Structures % change	No. Acres 1939	No. Acres 1963	No. Acres % change
A	8 Undeveloped	0	0	0	19	19	0
Tidal	Total	0	0	0	19	19	0
B	1 Industrial	0	4	na[2]	18	34	+89
	2 Commercial	4	24	+500	0	0	0
	4 Recreational	0	0	0	0	18	na
	6a Residential	13	232	+1685	32	32	0
	8 Undeveloped	0	0	0	41	2	-95
Tidal-10'	Total	19	262	+1279	91	91	0
C	1 Industrial	55	64	+16	36	112	+211
	2 Commercial	58	83	+43	16	60	+275
	3 Public	3	8	+167	0	12	na
	4 Recreational	6	7	+17	60	60	0
	6a Residential	198	331	+67	64	65	+2
	8 Undeveloped	0	0	0	210	77	-63
10'-20'	Total	324	495	+53	397	397	0
D	6a Residential	248	378	+52	73	72	-1
	8 Undeveloped	0	0	0	13	13	0
> 20'	Total	251	385	+53	89	89	0
F	2 Commercial	3	3	0	1	1	0
	4 Recreational	0	0	0	6	6	0
	6a Residential	118	124	+5	15	22	+47
	8 Undeveloped	0	0	0	13	6	-54
Flooded	Total	121	127	+5	35	35	0
All Zones	1 Industrial	55	68	+24	54	146	+170
	2 Commercial	65	113	+74	16	60	+275
	3 Public	4	10	+150	0	15	na
	4 Recreational	6	7	+17	63	81	+29
	5a Recreational	5	3	-40	8	8	0
	5b Recreational	0	0	0	3	6	+100
	6a Residential	459	941	+105	169	169	0
	8 Undeveloped	0	0	0	283	111	-61
	Total	594	1142	+92	596	596	0

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] na -- Calculation not appropriate.

6. Fairfield, Connecticut[1]

Fairfield is a manufacturing center on the Connecticut coast within communiting distance of New York City. The study site includes four miles of coastline between Southport Harbor in the west and Ash Creek in the east. This second example of the urban shore type of development has a total acreage of 1,678. (See figure 6 in the appendix.)

Physiography. Along the coast is a narrow, smooth beach averaging 50 feet in width and with a gentle gradient. Low, scattered, sand dunes occur along one-third of its length. Approximately six percent of the study site is made up of these beaches and dunes. Several of the beaches are popular as summer recreational areas.

Fairfield Beach is a small sand spit that has grown southwest for about one mile. The tip of this spit curves toward the northwest nearly closing off the tidal channel called Pine Creek. The growth and shape of the spit appear to be influenced by Kensie Point, a bedrock outcrop, which controls the movement of currents.

Most of the Fairfield study site is a low, rocky, seaboard lowland with tidal marshes in the wide depressions and scattered glacially scoured hills in the higher areas. The highest hill is called Sasco. This round bedrock hill is aligned in a north-south direction with a maximum elevation of 60 feet above sea level. This hill reaches the coast at Kensie Point where low, less than 10 foot high, rocky cliffs have been defaced and smoothed by waves.

Much of the mainland being less than 20 feet above sea level, is subject to tidal flooding. The materials making up the hilly uplands consist of both bedrock and fill, with a thin soil cover. The fill is largely made up of shallow glacial and marsh deposits. The marsh areas make up 22 percent of the study site, while the higher dry sections make up approximately 71 percent of the site. The remaining 7 percent is beach and dunes. Most of the tidal and fresh water marshes are covered with grasses growing in silt and clay fill. Large sections of these marsh areas have now become dry land through artificial filling.

The vegetation of the uplands consists of mixed coniferous and deciduous trees, herbaceous plants, and grasses. (See cross section, figure 2-6.)

Storm hazard. Much of the seaboard lowland is below 20 feet above mean sea level and is subject to coastal flooding. The Corps of Engineers Interim Hurricane Surveys of 1962 and 1964[2] set the flood of record for the Fairfield area at 10.1 and 10.8 feet above mean sea level. This flood record was set during the 1938 hurricane. The range for the

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[1] Field work by Robert Gardula and Roger Kasperson. We are indebted to the following persons who supplied information: Mr. Earl Rush, Mr. Frank Daniels, Mr. Tony Panico, Mr. Robert Bryan, and Mr. John J. Jrillivan.

[2] Corps of Engineer, Fairfield, Conn. Interim Hurricane Survey, 87th Congress, 2nd Session, House Document No. 600, 1962; and Hurricane Survey Interim Report, Connecticut Coastal and Tidal Areas, U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass., 22 May 1964, pp. 5-7.

whole Connecticut coast during the 1938 storm was 9.2 to 11.7 feet above mean sea level. The 1954 hurricane had comparable levels. It was found through field interviews that the flood of record varied between 9.5 and 10.5 feet. No appreciable flooding appears to have taken place since hurricane Carol in 1954 (the March 6-7 storm of 1962 was not severe along the New England coast).

Hurricanes moving north pose the biggest threat to this study site. The beaches appear to protect the coast to a level of about 6 feet above mean sea level. This protection is satisfactory for annual flooding from "northeasters" which seldom exceeds 4 to 5 feet, but it is not effective for severe hurricanes.

During severe storms the undermining of structures by waves and tidal surges is prevalent along the shore. In the last 25 years at least 25 to 35 cottages have been washed away. Once the waves rise above 6 feet, the low dunes and narrow beaches do not afford protection. As storm waves move inland to about one hundred yards from the beach, some cellar flooding can be expected to take place. Beyond one hundred yards, water damage becomes less but wind damage continues to affect structures. In all areas under 10 feet, streets can be expected to become inundated with about six inches of water during severe storms. [1]

Severe damage occurred at Fairfield in the hurricanes of 1938 and 1954. For the past ten years Fairfield has escaped major damage.

Settlement history.[2] The settlement of the Fairfield area began in 1639 when Roger Ludlow established the community of Uncoa (Fairfield). The settlement shortly became a military post and was strongly fortified. Population increased rapidly and agriculture flourished in the surrounding countryside. The settlement's growth was accelerated by legislation which made it a port of entry and also by the success of maritime activities. The town received a temporary setback during the Revolutionary War when it was burned by the British. The 1774 population of 4,863 was reduced to 3,735 at the end of the war.

During its early history the settlement was concentrated about the Post Road well away from the ocean, and with scattered farm homesteads in the northwest part of the town. Some coastal settlement was centered around Black Rock harbor but the remainder of the coast was undeveloped.

In the early part of the 19th century Fairfield remained a small community (population 4,246 in 1830) relying mainly on the agriculture and forestry of the surrounding

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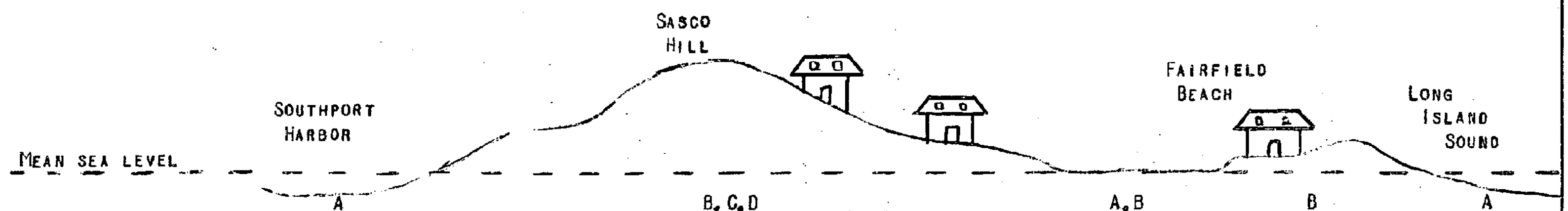
[1] Corps of Engineers, Fairfield, Conn. Interim Hurricane Survey, 87th Congress, 2nd Session, House Doc. No. 600, U.S. Govt. Printing Office, Washington, 1962, pp. 8-12; and Beach Erosion Control Report on Cooperative Study of Connecticut Area 1, Ash Creek to Saugatuck River, 7 Feb. 1949, Corps of Engineers, New England Division, Boston, Mass., pp. 3-20.

[2] Based on field party notes assembled from various locally available sources.

STUDY SITE NO. 6



	A	B, C, D	A, B	B	A
ZONE	BELOW MEAN HIGH TIDE	ABOVE MEAN HIGH TIDE TO OVER 20 FEET	BELOW MEAN HIGH TIDE, SOME FILLED AREAS ABOVE MEAN HIGH TIDE	ABOVE MEAN HIGH TIDE BUT BELOW 10 FEET	BELOW MEAN HIGH TIDE
GEOMORPHIC TYPE	TIDAL ESTUARY OF THE MILL RIVER	BEDROCK HILL COVERED WITH A THIN DEPOSIT OF GLACIAL TILL	TIDAL MARSH WITH SILTS AND CLAYS	SAND SPIT	NARROW SANDY BEACH
TYPE OF HAZARD	FLOODING	NO FLOODING	TIDAL INUNDATION AND SOME EROSION	FLOODING, EROSION, DAMAGE TO STRUCTURES	EROSION OF BEACH
DEGREE OF HAZARD	MINOR	NONE	MINOR	SEVERE	SEVERE
STRUCTURES	NONE	FEW	FEW	MANY	FEW
ADJUSTMENTS	DEEPENING OF THE CHANNEL, SOME PROTECTIVE WORKS	FEW	FILL	LOW DIKES AND BULKHEADS	JETTIES, GROINS AND SAND FILL TO PROTECT BEACH

FIGURE 2-6. DIAGRAMMATIC CROSS SECTION, FAIRFIELD, CONNECTICUT

area and on the fishing industry. Rail connections were established in 1849 and thereafter Fairfield became more of a manufacturing center. It was not until the 20th century, however, that the coastal areas were developed. During the period before 1930, contemporaneously with an increased use of private cars, the coastal areas began to be developed as a summer resort. The high density of settlement which now prevails may be attributed in part to the lack of zoning ordinances which might have required larger size lots.

Land use changes. There have been only small changes of land use in the study area between the date of the first available air photograph coverage in 1951 and the time of field work in 1963. By 1951 all the area was in some form of developed land use and the small increase in single family residences has been by a process of intensification of existing land use. The new single family residences have been built mainly at the southern ends of Beach Road, Reef Road and Penfield Road. Field observations indicate that over half of the new structures are in the flood hazard zone.

Along the shore west of Shoal Point the number of structures has actually been reduced as a result of Hurricane Carol in 1954. This storm washed out a section of the spit carrying with it about 15 houses. These have not been replaced.

There have been some small developments along the edge of the swamp, where land has been reclaimed by fill. Within the swamp itself several hundred acres of land were purchased by the Federal Government for the construction of a Nike missile site.

Starting in 1963 work began on the expansion and modernization of the existing marina along Ash Creek. Plans for a new marina which would utilize about a hundred acres of the marshland have also been drawn up. There has been a small increase in flood damage potential at Fairfield since 1951 but there is unlikely to be much further increase in view of the already highly developed nature of the study area. Land use is shown in the overlay to figure 6 (appendix), and recorded land use changes are given in table 2-6.

Adjustments to hazard. In view of the record of past damage, the inhabitants of the coastal area of Fairfield seem remarkably complacent about the likelihood of future damage. This may be partly due to the absence of a major damaging storm since 1954. It may also be partly due to the construction of a system of partial protection works. The town has constructed a system of dikes which help to reduce flooding although they afford little protection to the shore-front properties. In addition a number of groins afford partial flood protection and help the development of beaches by sand deposition.

Local confidence in the protective power of the dikes along Ash Creek and South Pine Creek is high and many citizens believe that the flood problem has been solved. The Town Engineer is not so confident. He believes that the dikes afford adequate protection from 7 or 8 out every 10 major storms and hurricanes, but feels that this is not sufficient and that extra protection should be provided.

The U.S. Army Corps of Engineers have in fact made a proposal to provide additional protection by the construction of a seawall. Fairfield has rejected this proposal

Table 2-6

Fairfield, Connecticut

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures 1951	No. Structures 1963	No. Structures % change	No. Acres 1951	No. Acres 1963	No. Acres % change
A	3 Public	0	4	na[2]	9	24	+167
	5b Recreational	0	0	0	14	14	0
	6a Residential	13	13	0	1	1	0
	8 Undeveloped	0	0	0	234	219	-6
Tidal	Total	13	17	+31	262	262	0
B	2 Commercial	15	18	+20	15	15	0
	3 Public	1	4	+300	19	36	+90
	5b Recreational	1	1	0	162	162	0
	6a Residential	1152	1202	+4	430	430	0
	8 Undeveloped	0	0	0	126	109	-14
Tidal-10'	Total	1175	1232	+5	789	789	0
C	2 Commercial	92	92	0	39	39	0
	3 Public	15	15	0	52	52	0
	6a Residential	341	377	+11	209	209	0
	8 Undeveloped	0	0	0	31	31	0
10'-20'	Total	457	493	+8	346	346	0
D	5b Recreational	0	0	0	28	28	0
	6a Residential	125	125	0	219	233	+6
	8 Undeveloped	0	0	0	31	17	-45
> 20'	Total	132	132	0	281	281	0
F	2 Commercial	12	15	+25	8	11	+38
	3 Public	1	3	+200	18	72	+300
	5b Recreational	1	1	0	279	279	0
	6a Residential	728	774	+6	324	337	+4
	8 Undeveloped	0	0	0	552	480	-13
Flooded	Total	749	800	+7	1217	1217	0
All	1 Industrial	2	3	+50	8	8	0
Zones	2 Commercial	114	117	+3	57	57	0
	3 Public	16	23	+44	80	112	+40
	4 Recreational	1	1	0	26	26	0
	5a Recreational	1	1	0	10	10	0
	5b Recreational	1	1	0	212	212	0
	6a Residential	1613	1717	+5	859	873	+2
	6b Residential	11	11	0	4	4	0
	8 Undeveloped	0	0	0	422	376	-11
	Total	1777	1874	+6	1678	1678	0

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] na -- Calculation not appropriate.

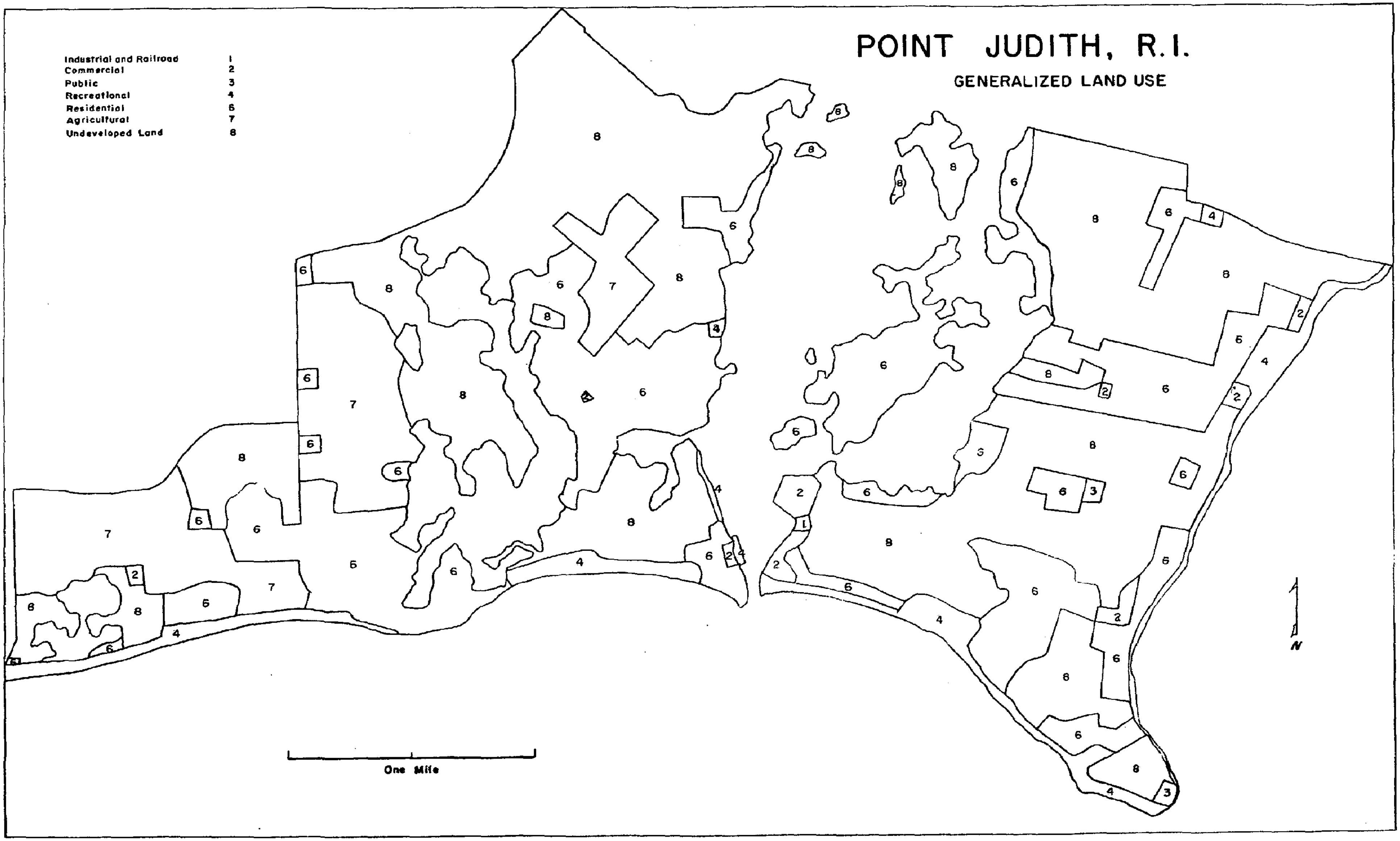


Figure 1 - Overlay

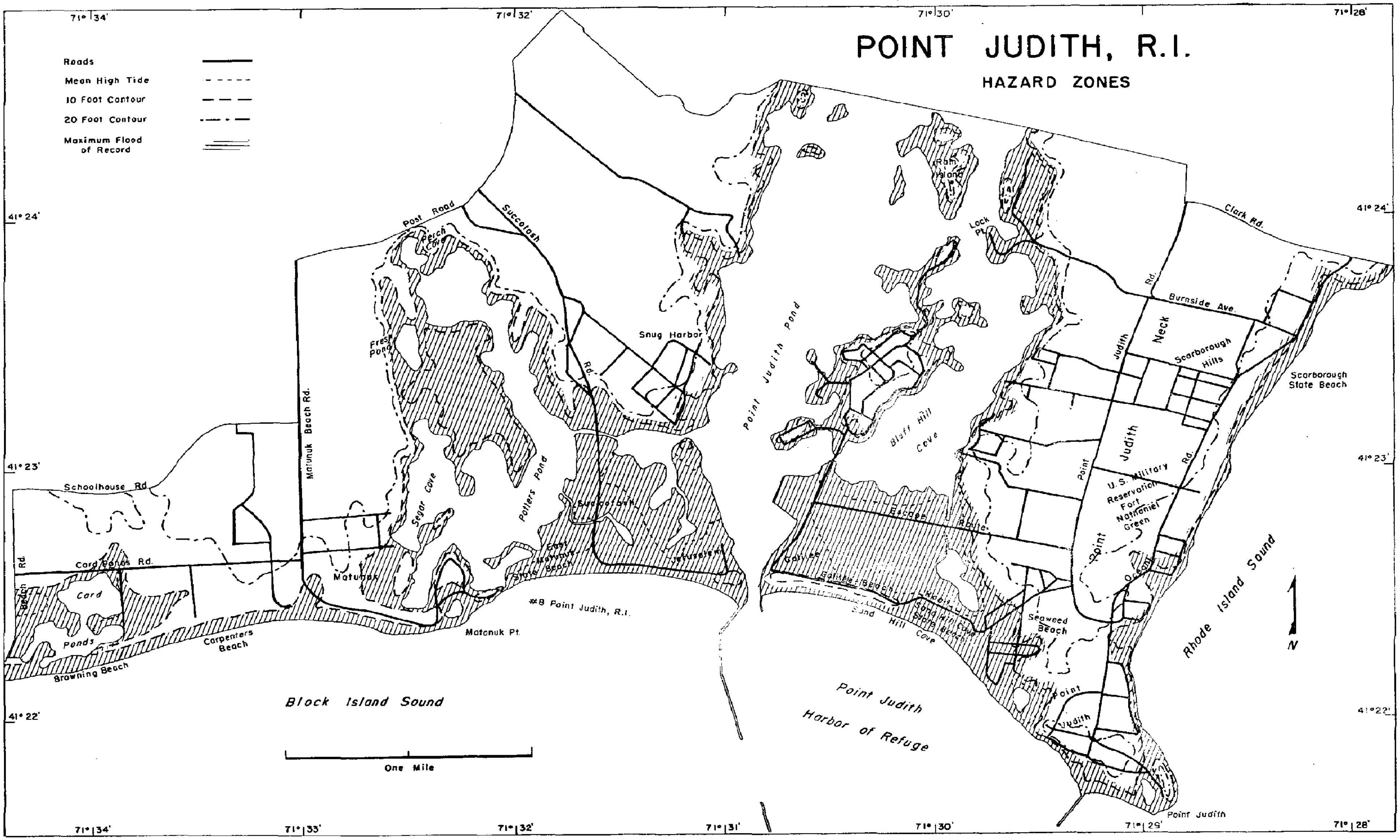

POINT JUDITH, R.I.
HAZARD ZONES
Roads
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record
Block Island Sound
One Mile
Point Judith Harbor of Refuge
Rhode Island Sound
Point Judith Pond
Bluff Hill Cove
Potters Pond
Segar Cove
Matunuk Beach Rd.
Schoolhouse Rd.
Card Ponds Rd.
Beach Rd.
Card Ponds
Browning Beach
Carpenters Beach
Matunuk Pt.
#8 Point Judith, R.I.
Post Road
Succotash Rd.
Snug Harbor
Lock Pt.
Clark Rd.
Burnside Ave.
Judith Rd.
Point Judith Neck
Scarborough Hills
Scarborough State Beach
U.S. Military Reservation
Fort Nathaniel Green
Ocean Rd.
Seaweed Beach
Sand Hill Cove
Escape Route
Galilee
Point Judith
N
71° 34'
71° 33'
71° 32'
71° 31'
71° 30'
71° 29'
71° 28'
41° 24'
41° 23'
41° 22'

Figure 1

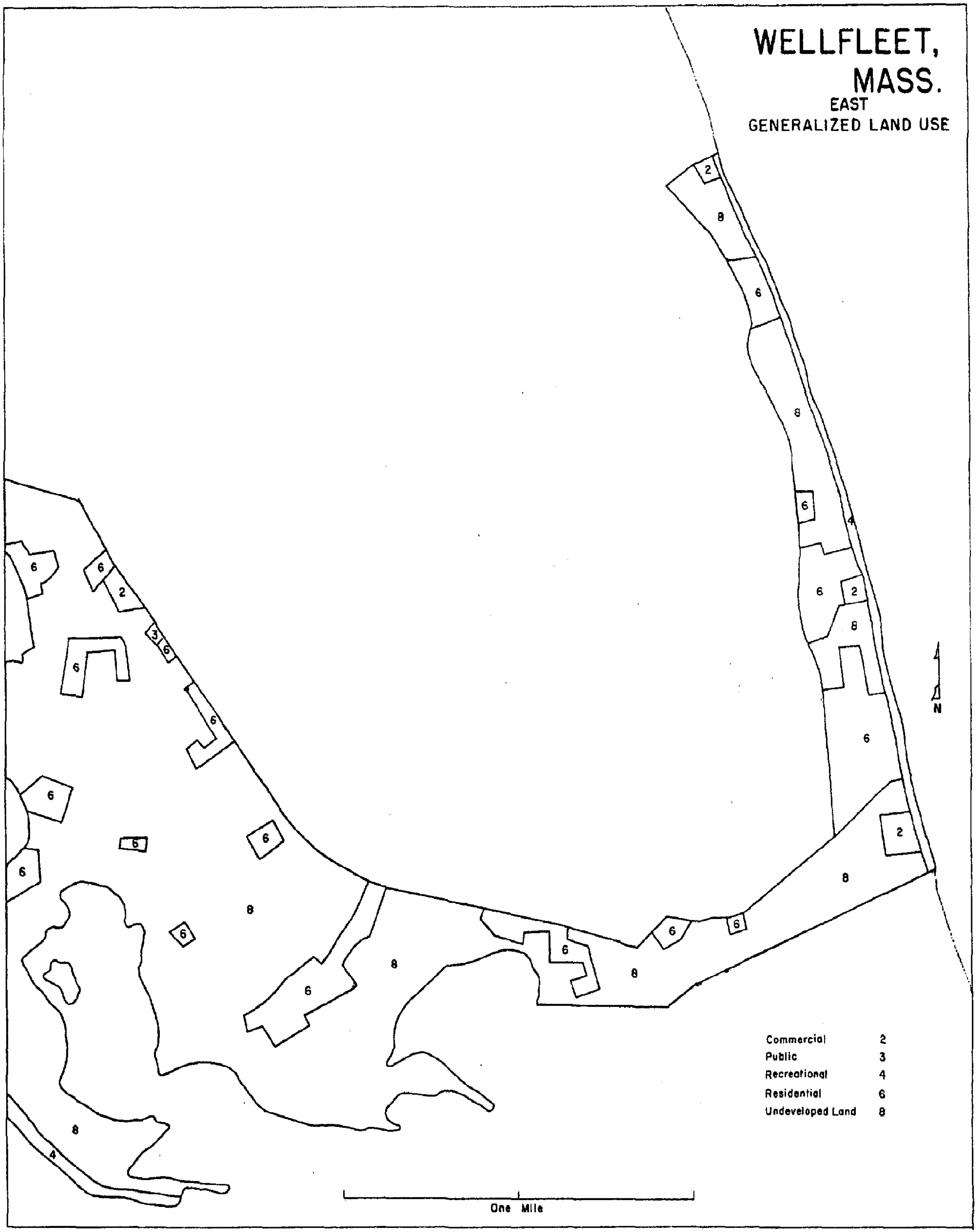


Figure 2 - Overlay

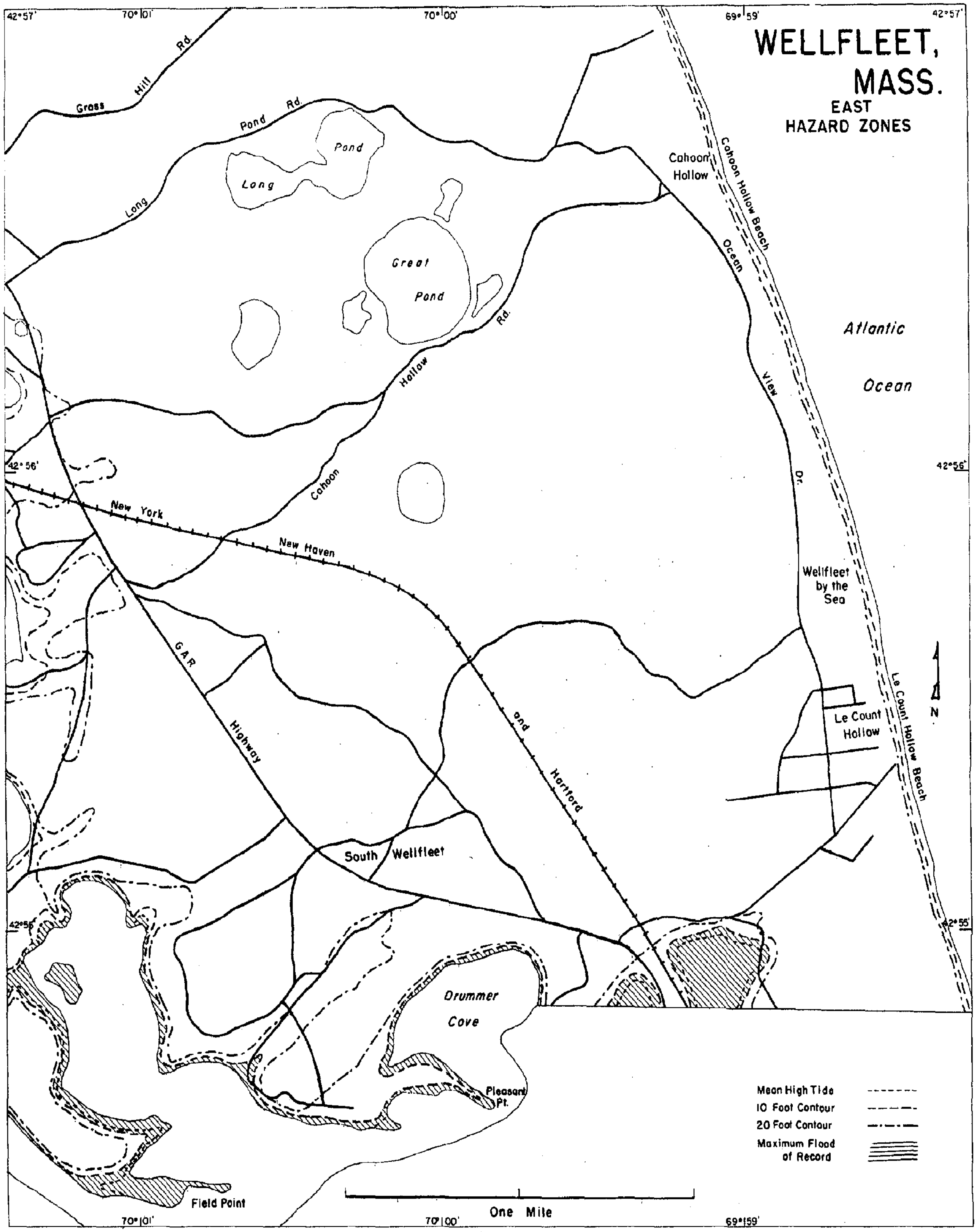

WELLFLEET, MASS.
EAST
HAZARD ZONES
42°57'
70°01'
70°00'
69°59'
42°56'
42°55'
Grass Hill Rd.
Long Pond Rd.
Long Pond
Great Pond
Cahoon Hollow Rd.
Cahoon Hollow
Cahoon Hollow Beach
Ocean View Dr.
Atlantic Ocean
New York New Haven and Hartford
GAR Highway
Wellfleet by the Sea
Le Count Hollow
Le Count Hollow Beach
N
South Wellfleet
Drummer Cove
Pleasant Pt.
Field Point
One Mile
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record

Figure 2

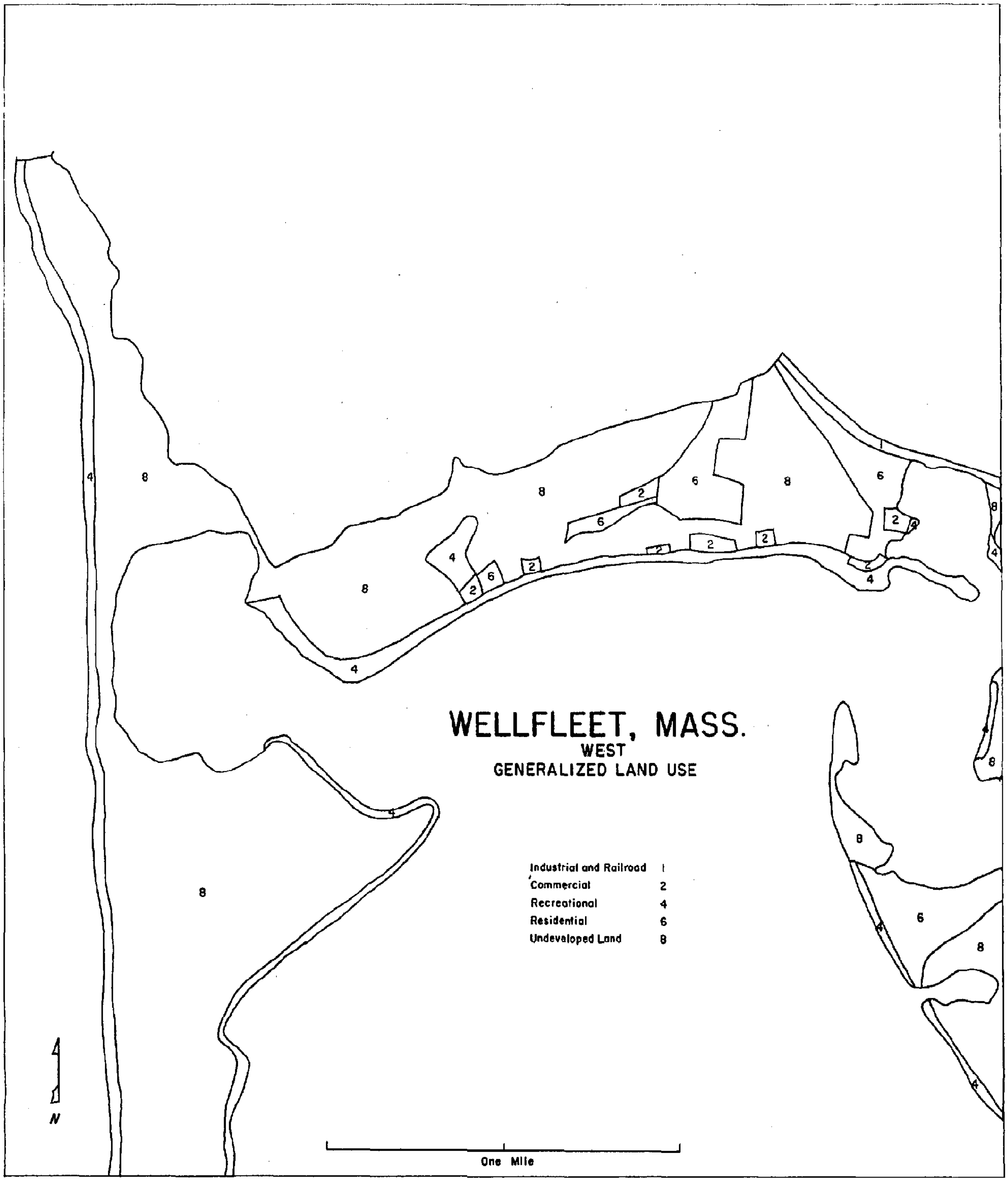


Figure 2a-Overlay

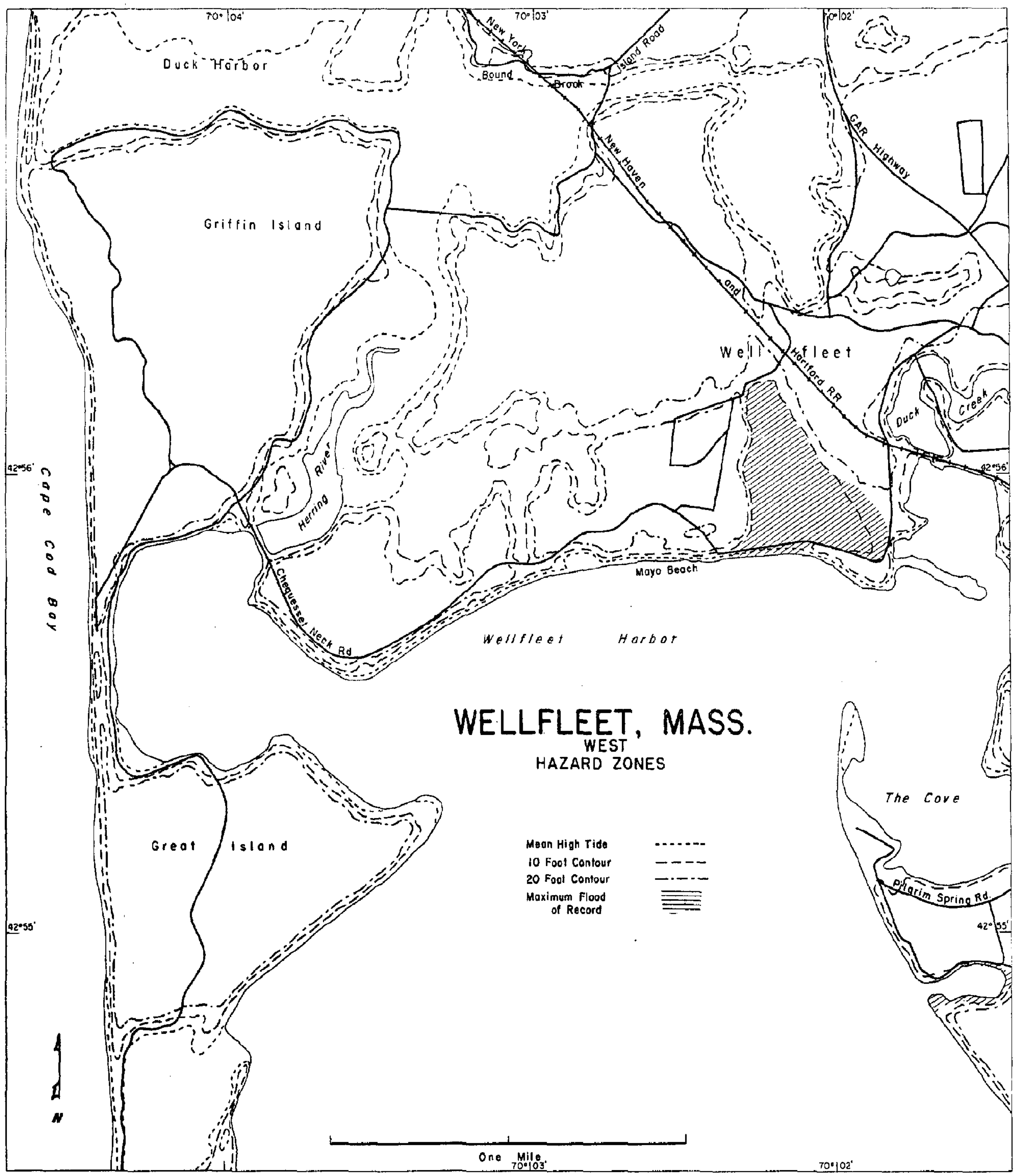

WELLFLEET, MASS.
WEST
HAZARD ZONES
Duck Harbor
Griffin Island
Great Island
Cape Cod Bay
Herring River
Chequesset Neck Rd
Mayo Beach
Wellfleet Harbor
Wellfleet
New York New Haven and Hartford RR
Bound Brook
Island Road
Highway
Duck Creek
The Cove
Pilgrim Spring Rd.
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record
One Mile
N
70°04'
70°03'
70°02'
42°56'
42°55'

Figure 2a

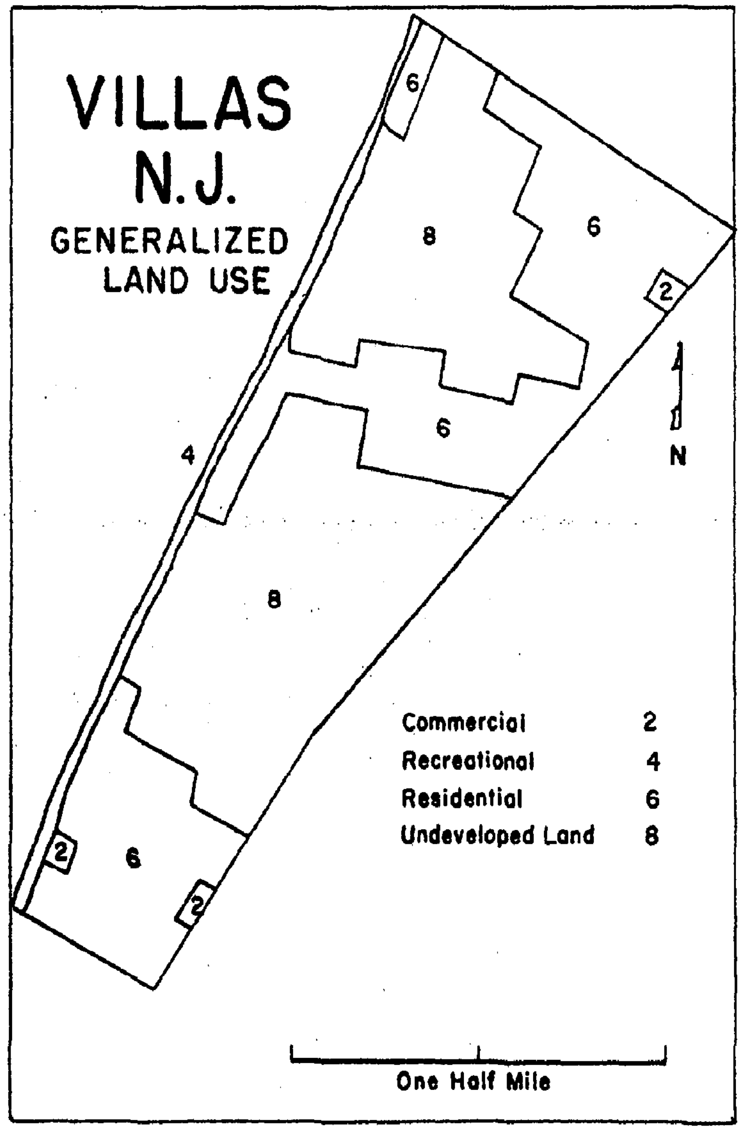
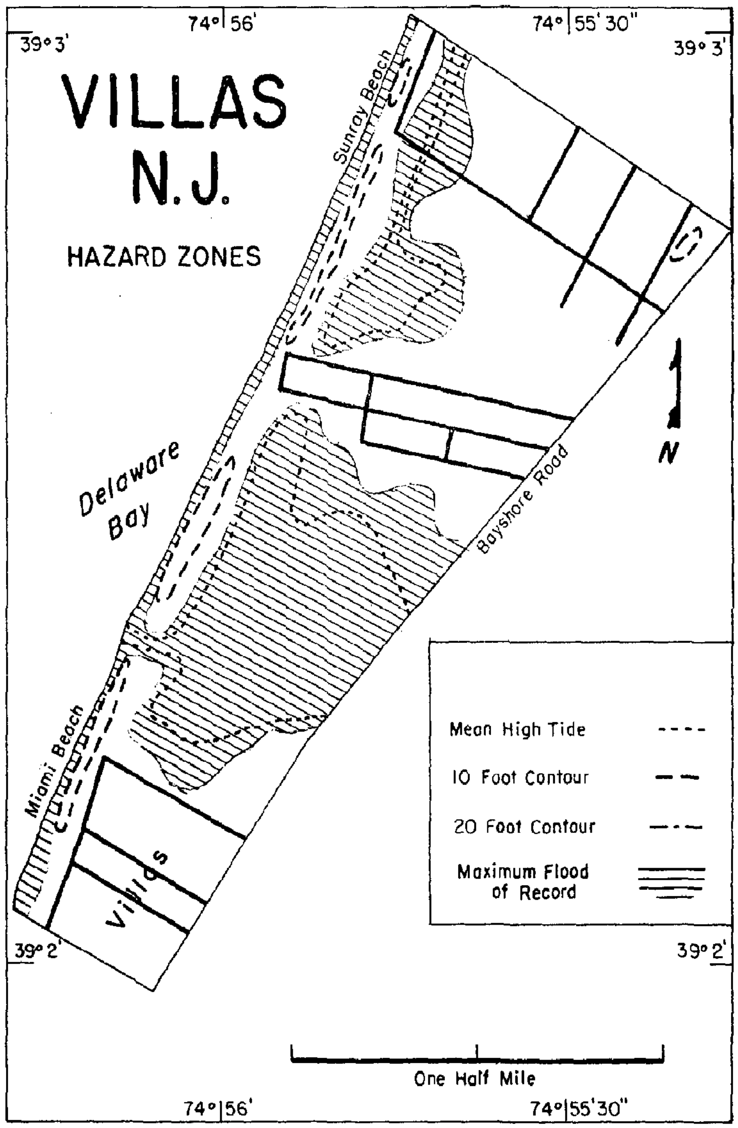
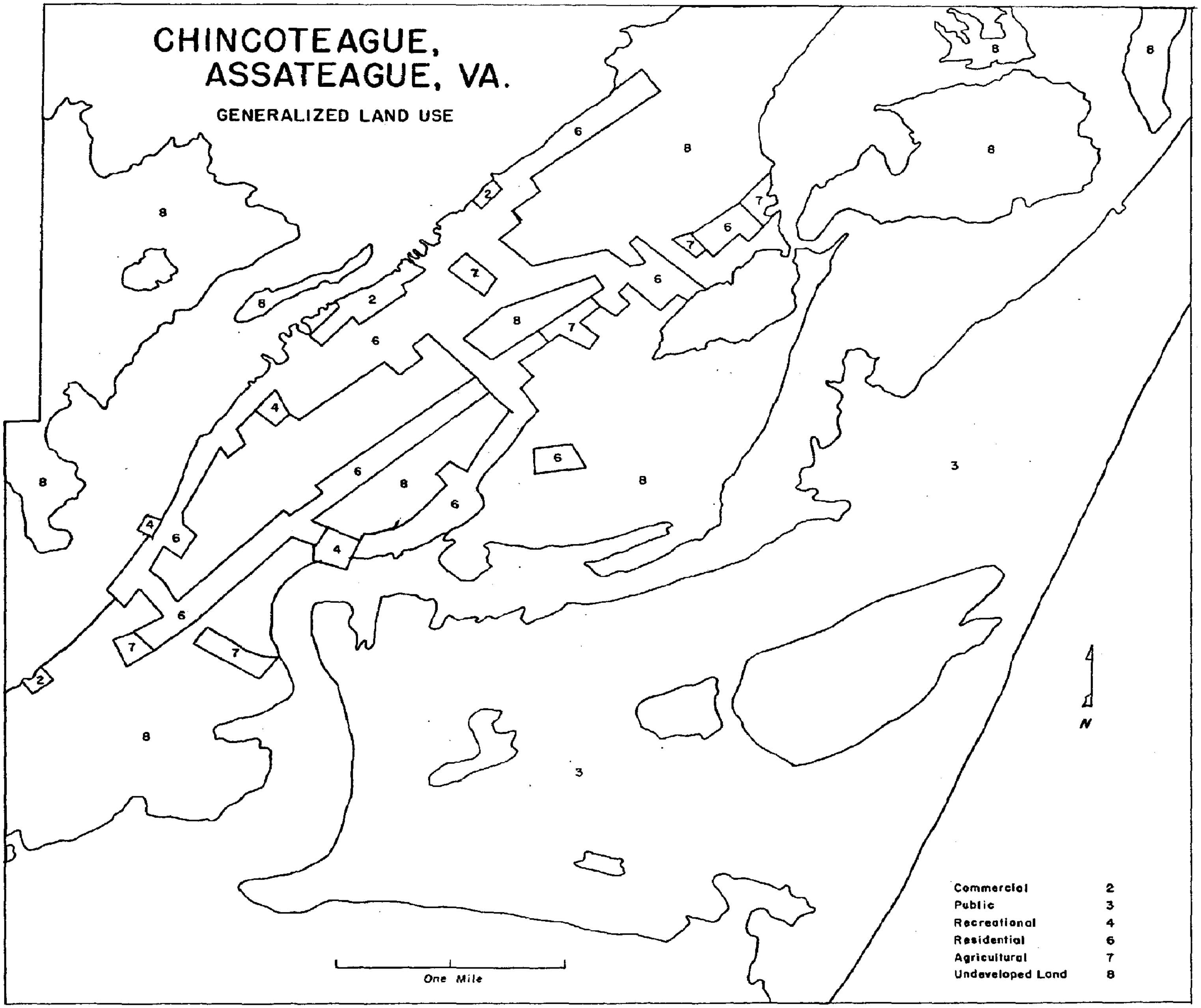


Figure 3 - Overlay

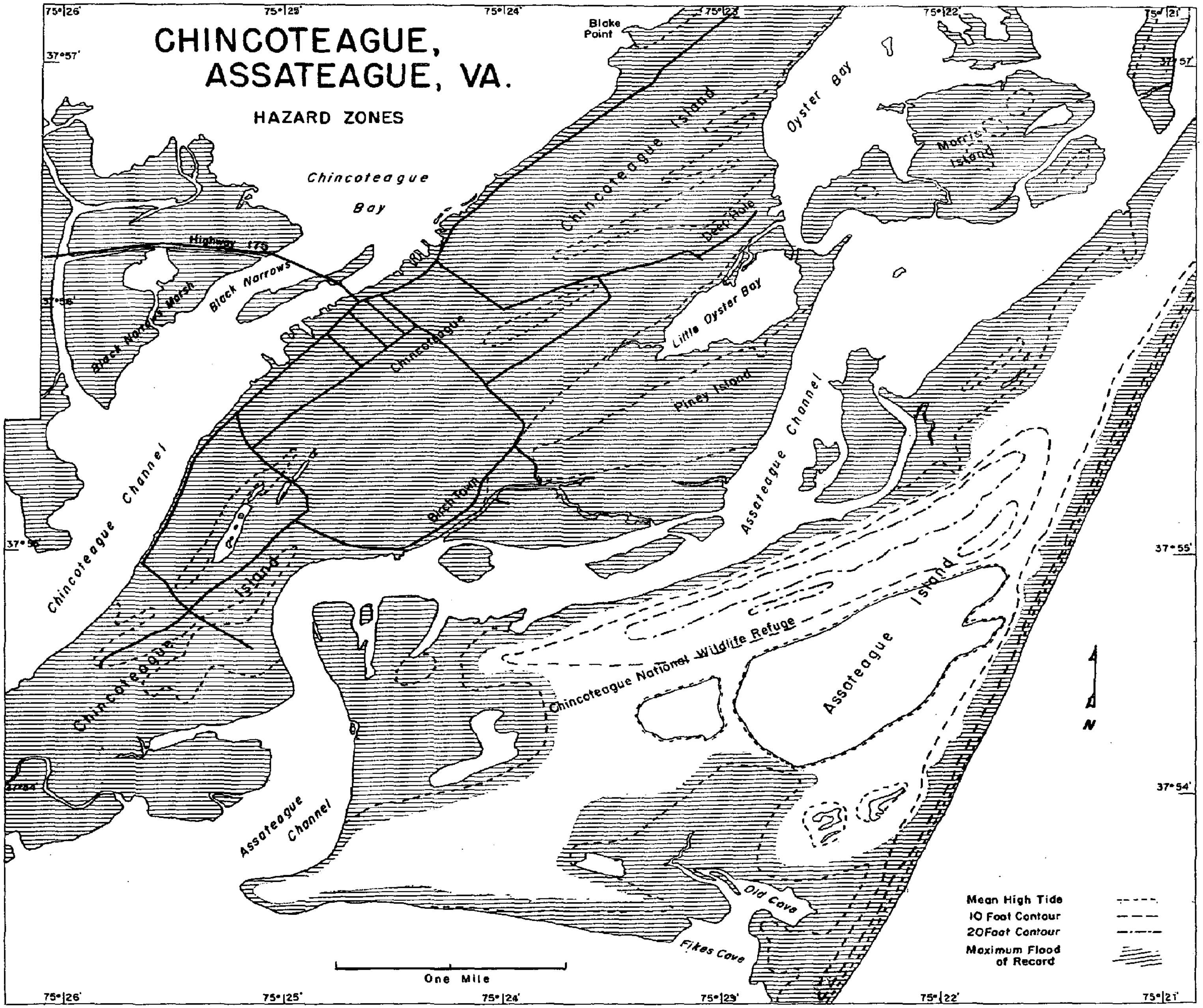


74°56'
74°55'30"
39°3'
39°3'
VILLAS
N.J.
HAZARD ZONES
Sunray Beach
Delaware Bay
Bayshore Road
N
Miami Beach
Villas
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record
39°2'
39°2'
One Half Mile
74°56'
74°55'30"

Figure 3



Figures 4 and 15 - Overlay



Figures 4 and 15

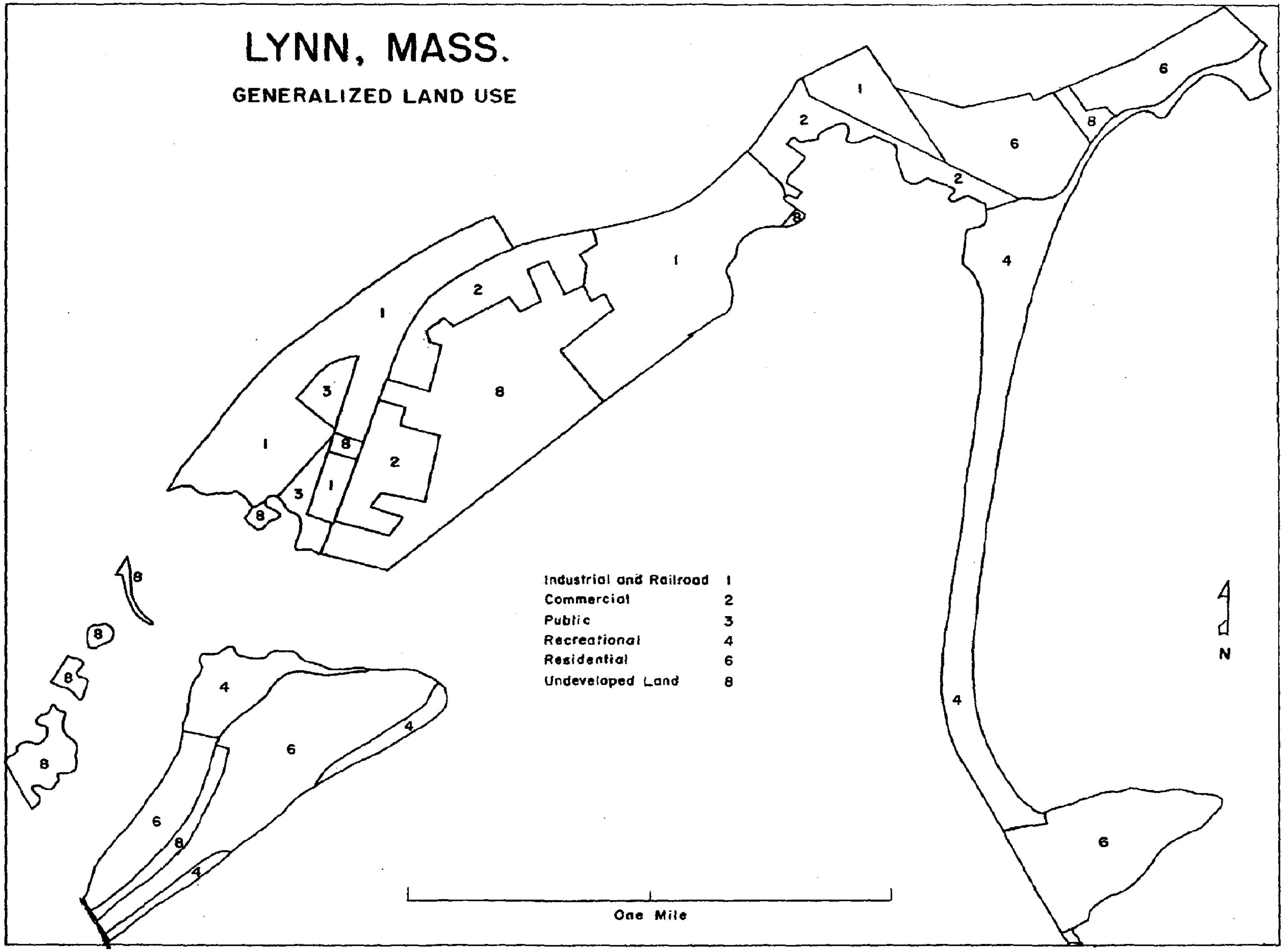
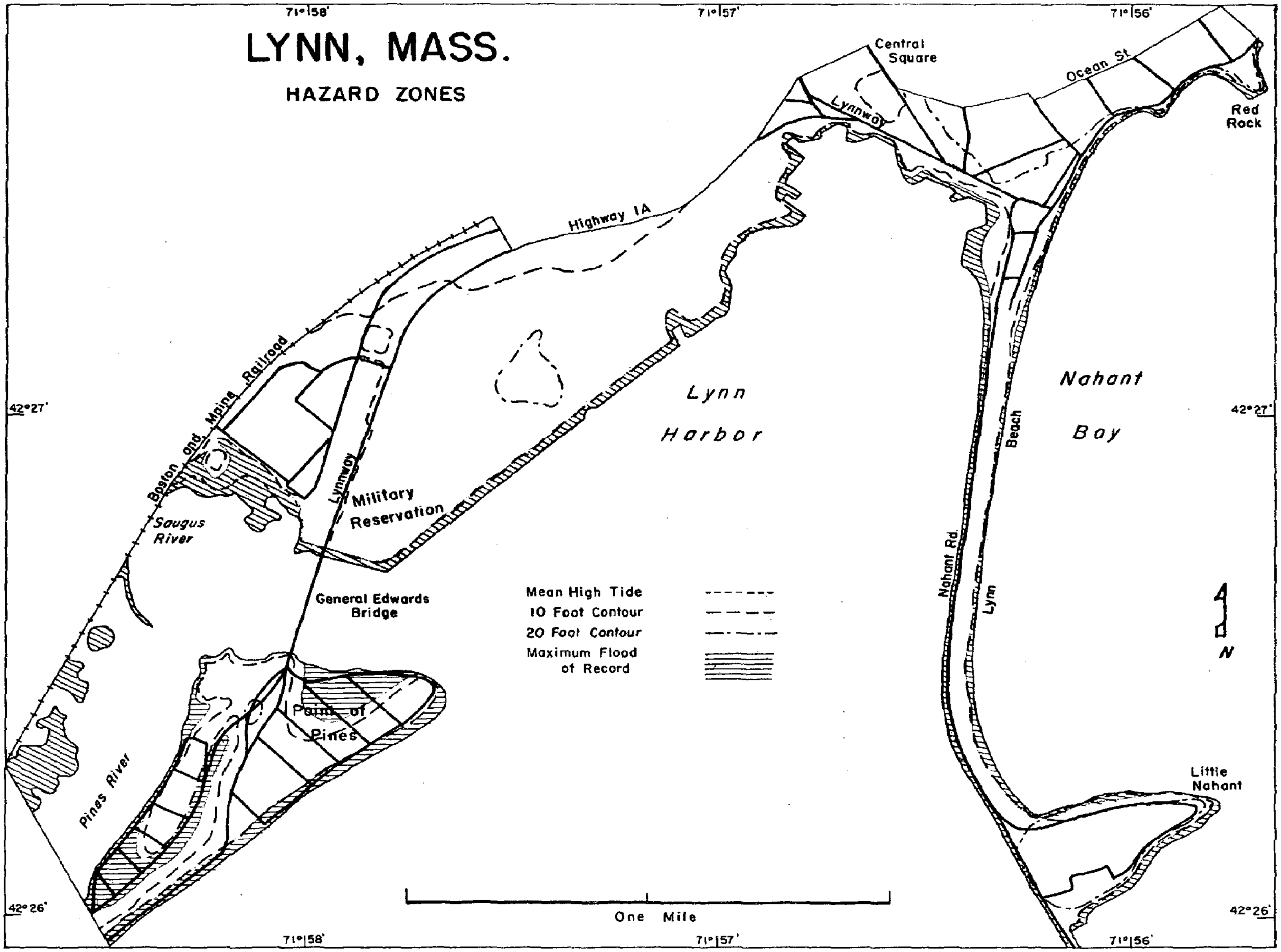


Figure 5 - Overlay


LYNN, MASS.
HAZARD ZONES
71°58'
71°57'
71°56'
42°27'
42°26'
Central Square
Ocean St.
Red Rock
Lynnway
Highway 1A
Boston and Maine Railroad
Saugus River
Military Reservation
Lynn Harbor
Nahant Bay
Lynn Beach
Nahant Rd.
Little Nahant
General Edwards Bridge
Point of Pines
Pines River
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record
One Mile
N
Figure 5

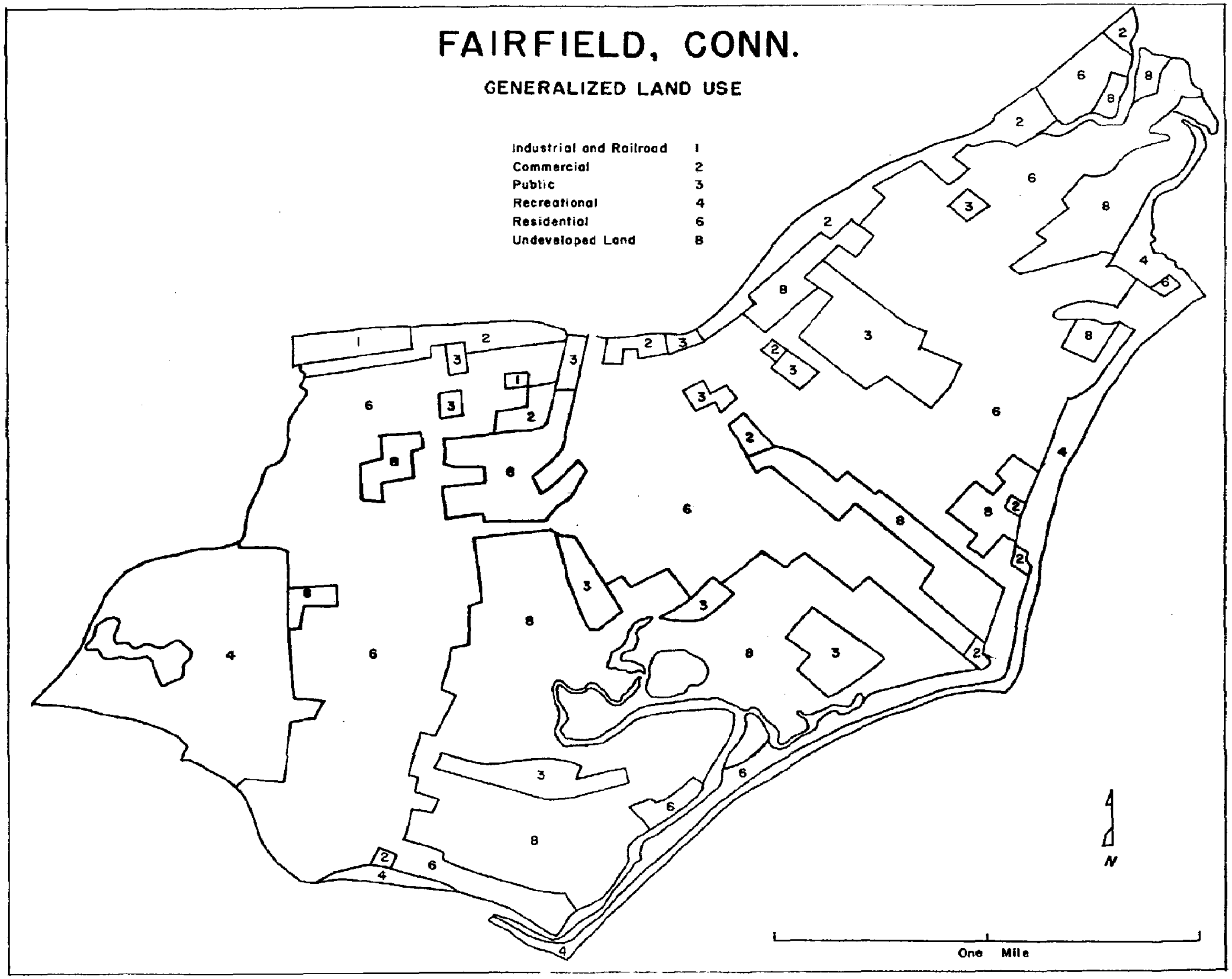


Figure 6 - Overlay

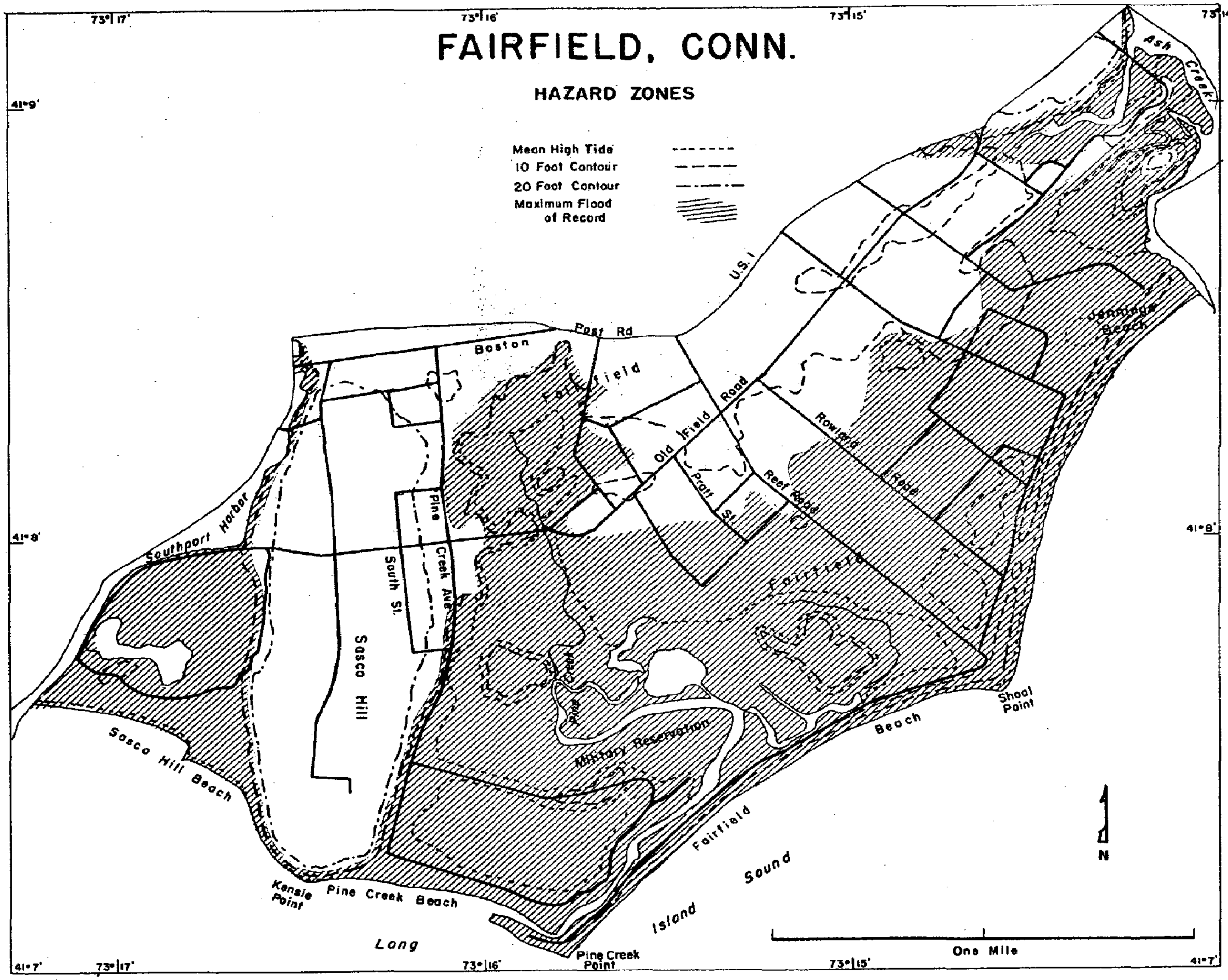
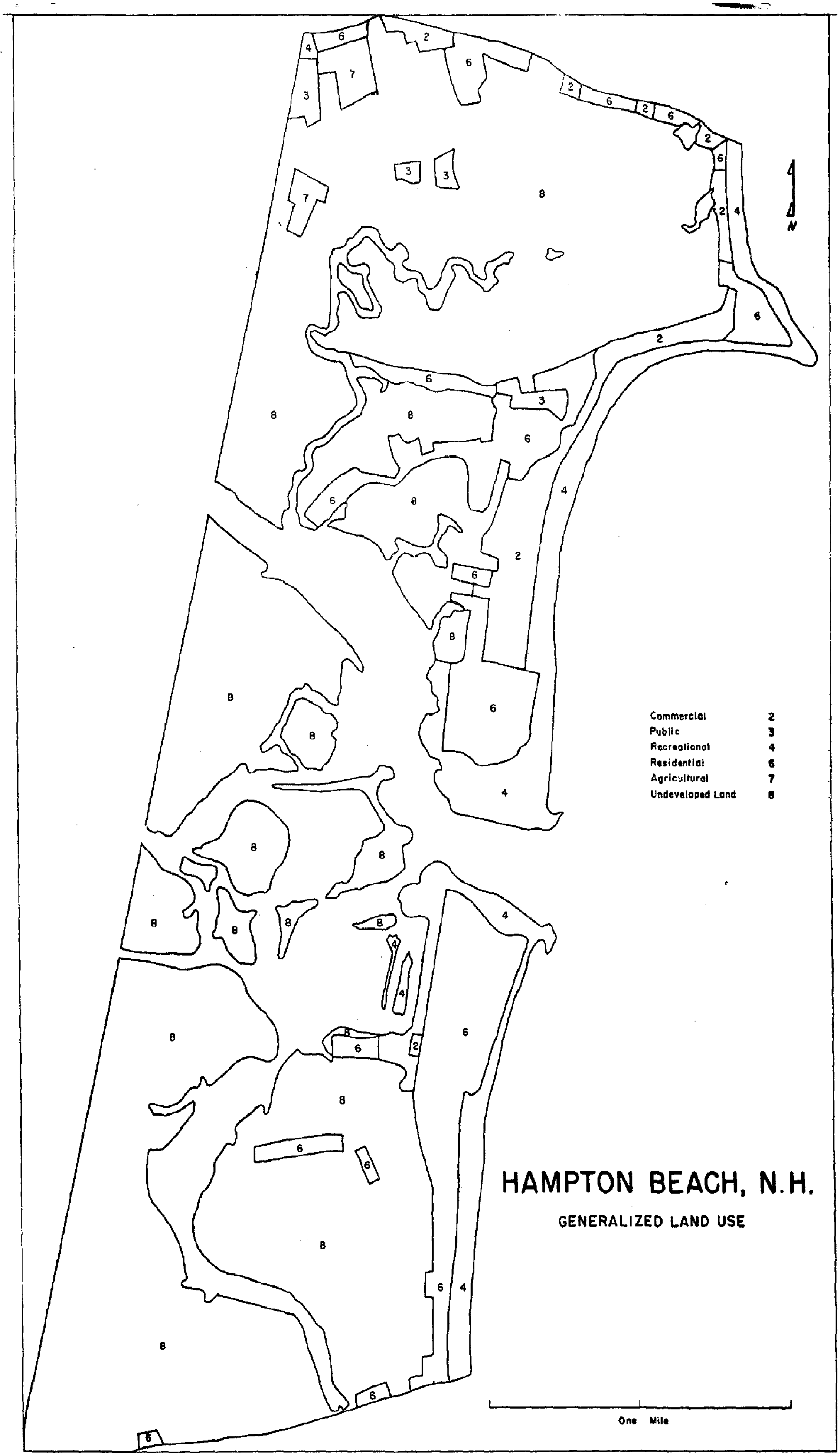
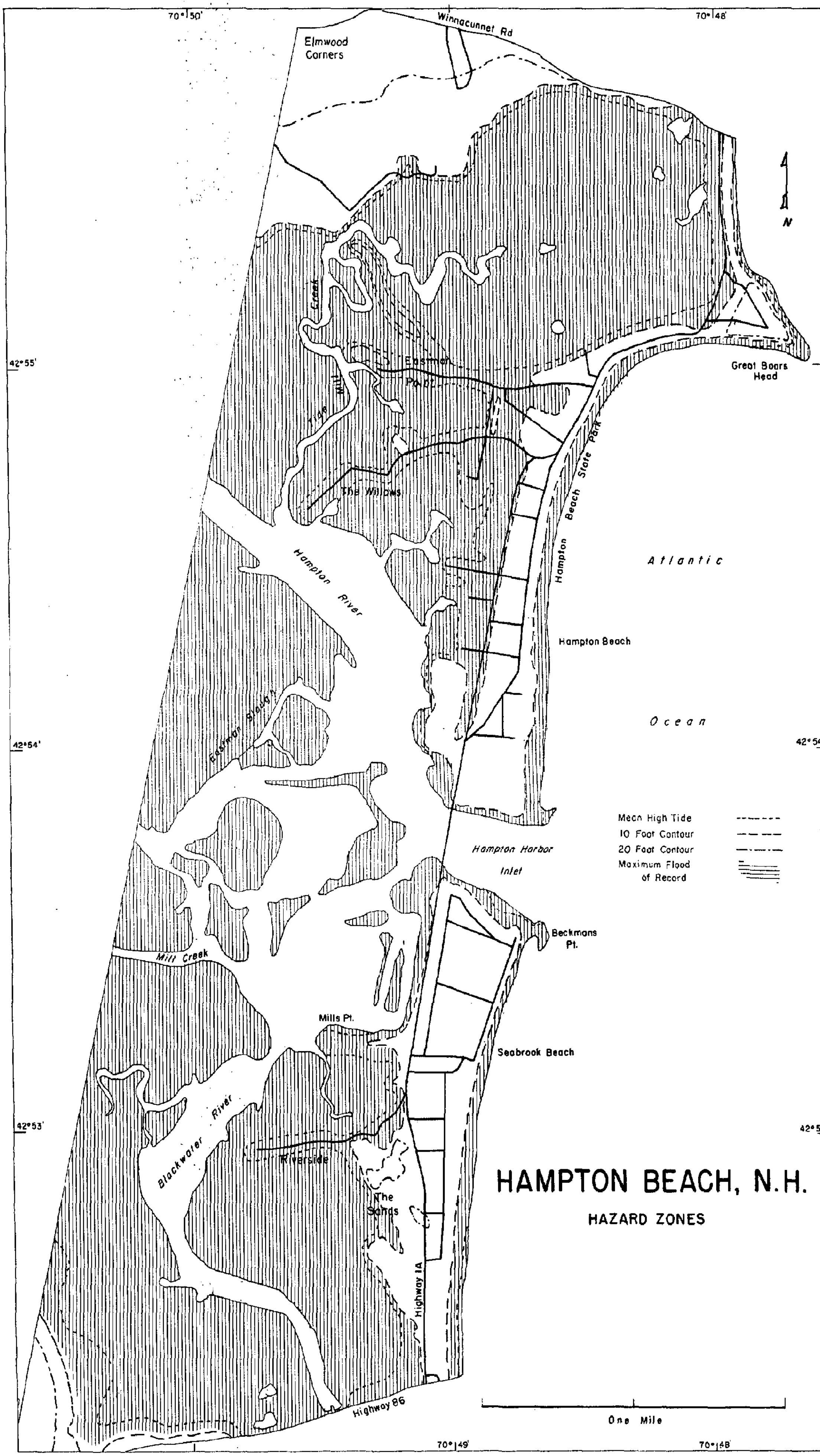

FAIRFIELD, CONN.
HAZARD ZONES
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record
73°17'
73°16'
73°15'
73°14'
41°9'
41°8'
41°7'
Ash Creek
Jennings Beach
U.S. 1
Boston Post Rd
Fairfield
Old Field Road
Rowland Road
Reef Road
Pratt St.
Pine Creek Ave
South St.
Sasco Hill
Southport Harbor
Sasco Hill Beach
Kensie Point
Pine Creek Beach
Pine Creek Point
Military Reservation
Fairfield Beach
Shoal Point
Long Island Sound
N
One Mile

Figure 6



Fiaure 7 - Overlav



HAMPTON BEACH, N.H.

HAZARD ZONES

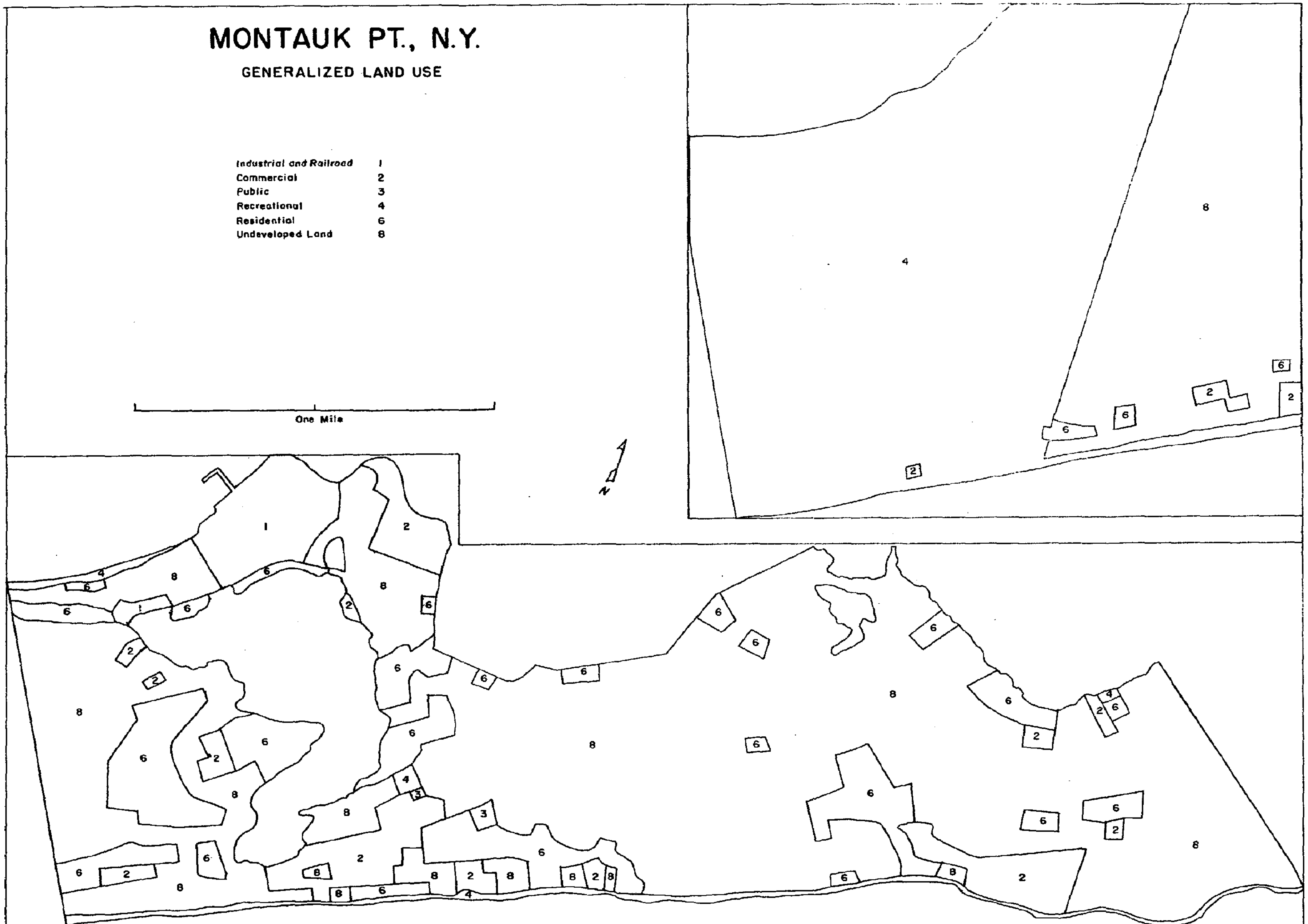


Figure 8 - Overlay

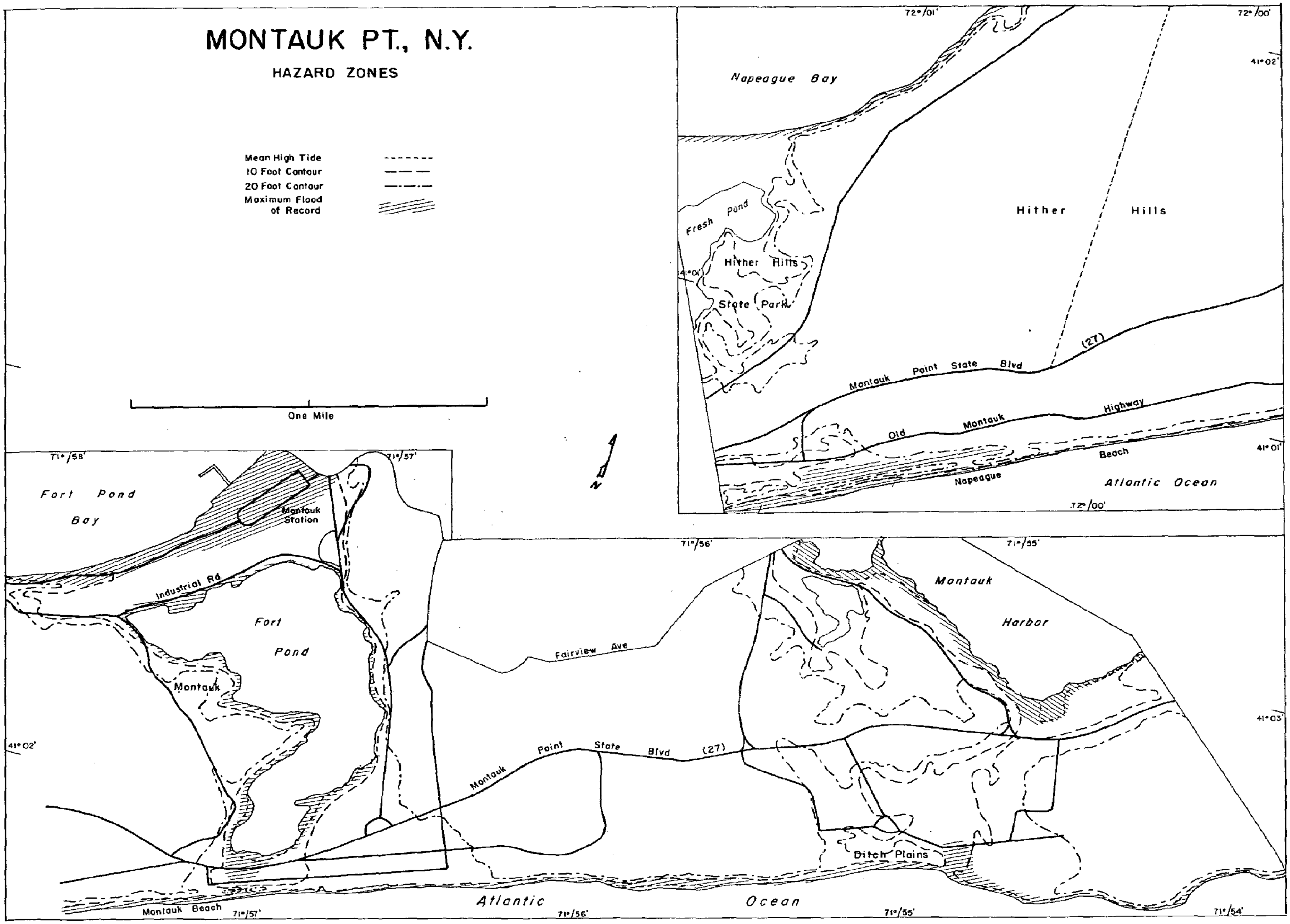

MONTAUK PT., N.Y.
HAZARD ZONES
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record
One Mile
Napeague Bay
Fresh Pond
Hither Hills State Park
Hither Hills
Montauk Point State Blvd
(27)
Old Montauk Highway
Napeague Beach
Atlantic Ocean
72°/01'
72°/00'
41°02'
41°01'
Fort Pond Bay
Montauk Station
Industrial Rd.
Fort Pond
Montauk
Fairview Ave
Montauk Harbor
Ditch Plains
Ocean
Montauk Beach
71°/58'
71°/57'
71°/56'
71°/55'
71°/54'
41°03'

Figure 8

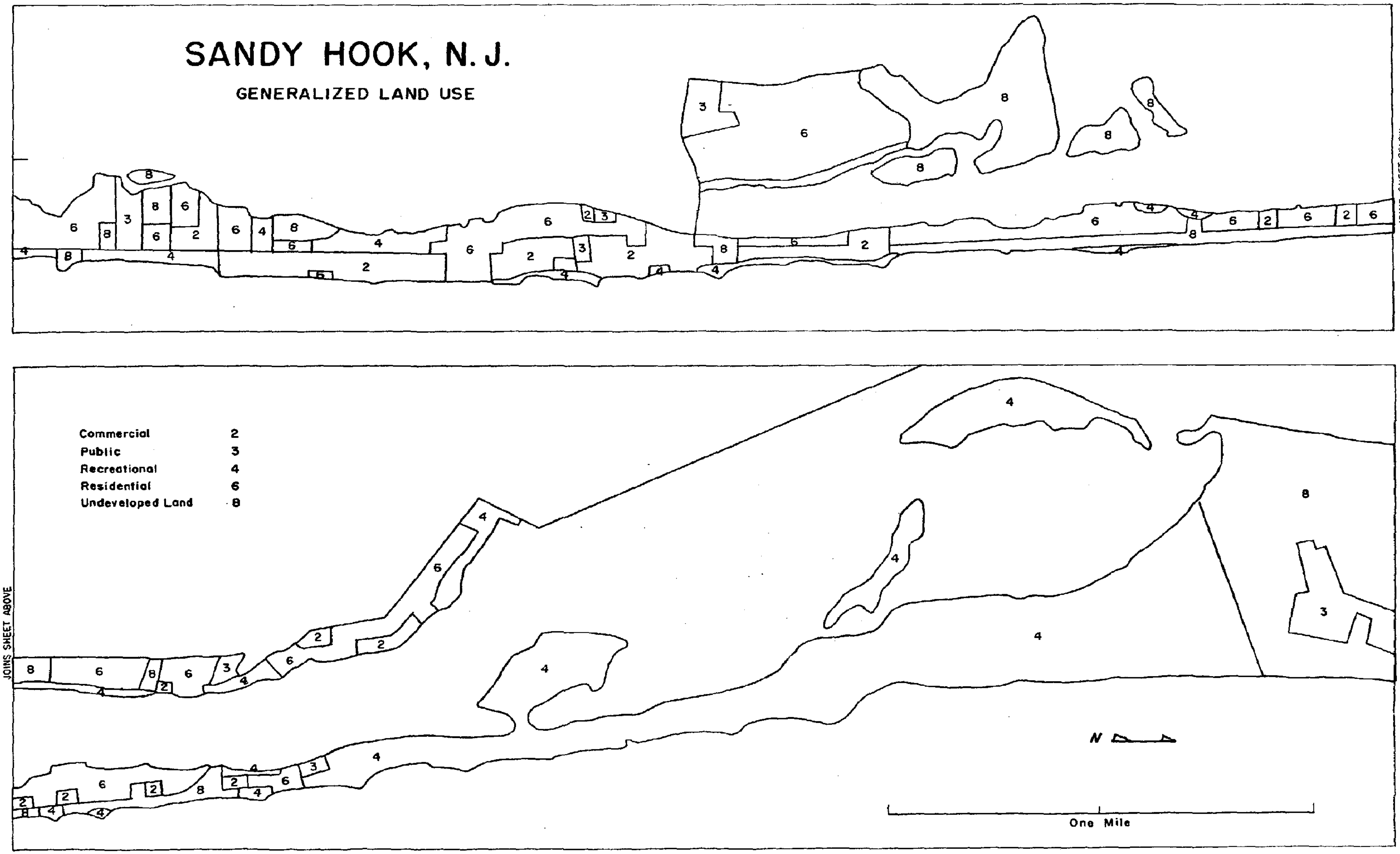
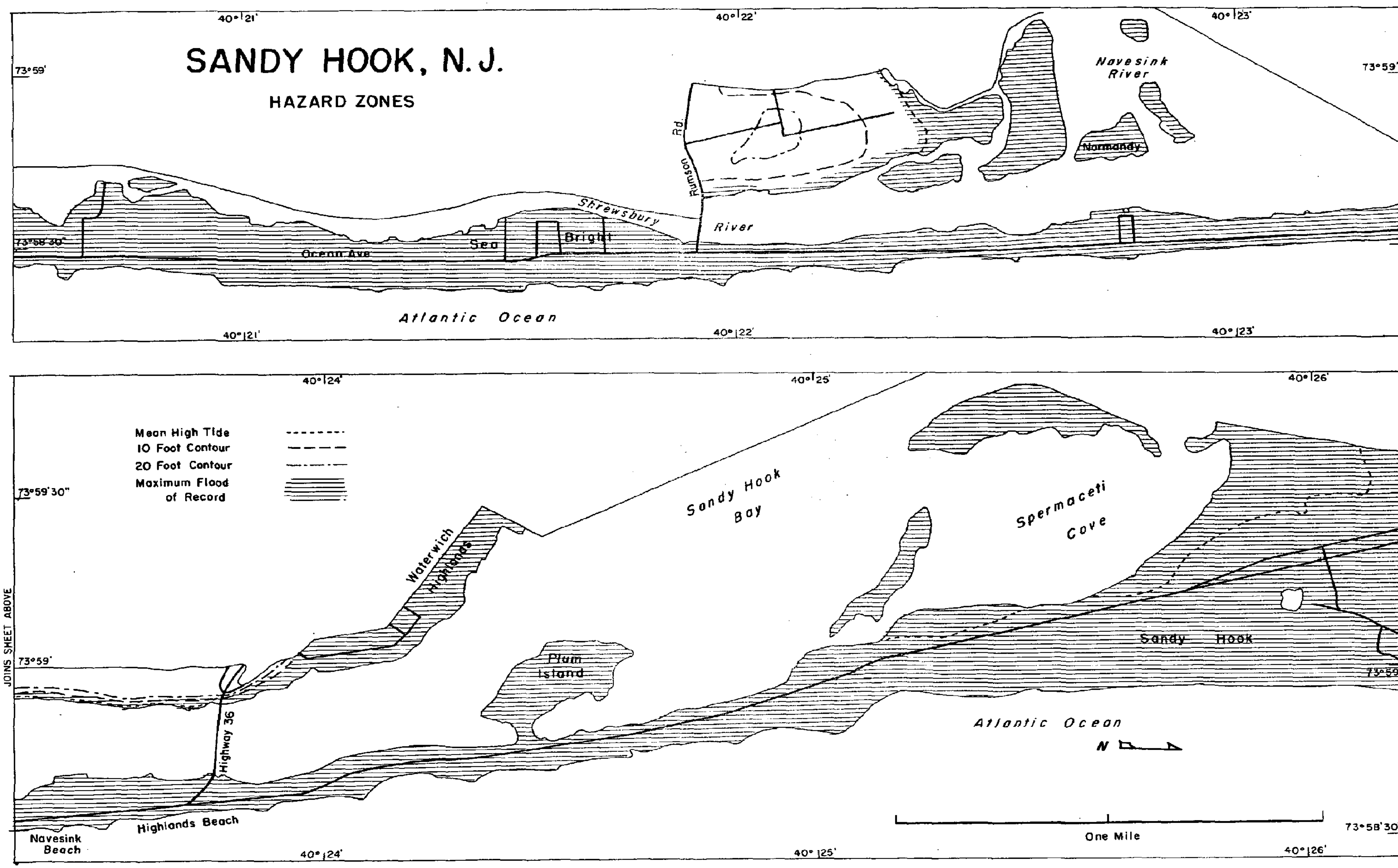


Figure 9 - Overlay



SANDY HOOK, N.J.
HAZARD ZONES
40°21'
40°22'
40°23'
73°59'
73°58'30"
Ocean Ave
Sea
Bright
Shrewsbury
River
Rumson
Rd.
Navesink
River
Normandy
JOINS SHEET BELOW
Atlantic Ocean
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood
of Record
40°24'
40°25'
40°26'
73°59'30"
73°58'30"
JOINS SHEET ABOVE
Waterwich
Highlands
Sandy Hook
Bay
Plum
Island
Spermaceti
Cove
Sandy Hook
Highway 36
Highlands Beach
Navesink
Beach
N
One Mile

Figure 9

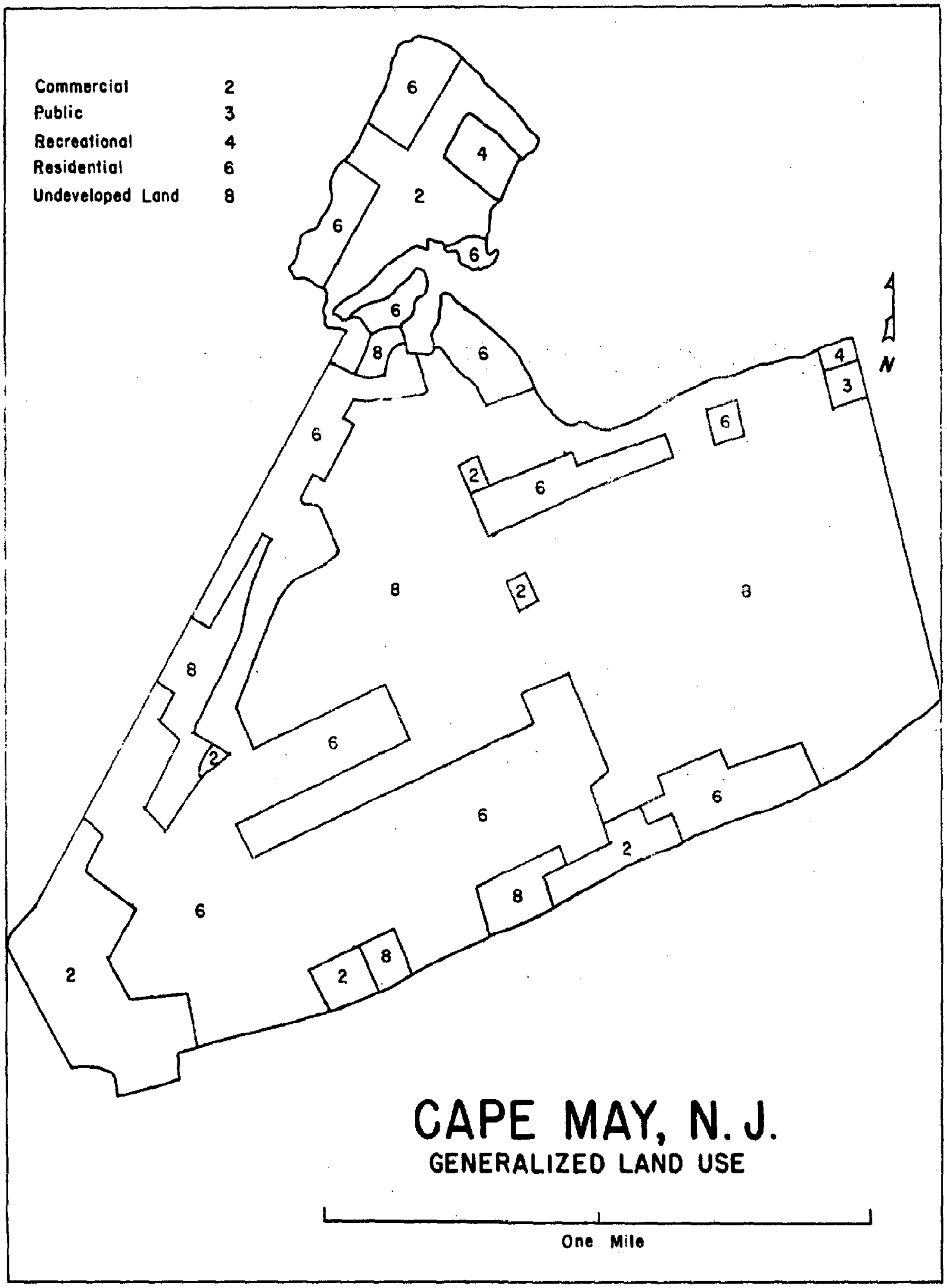
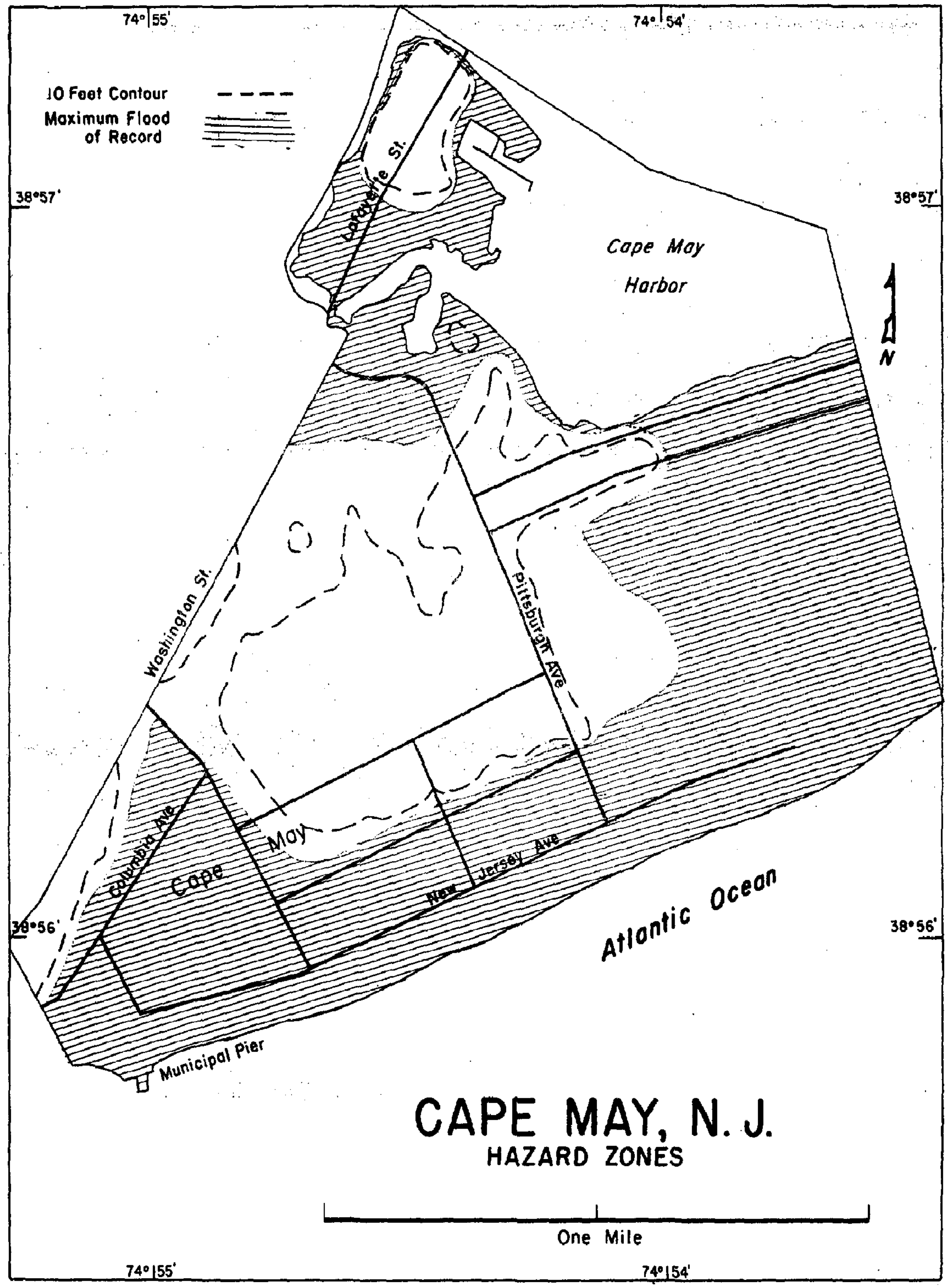


Figure 10 - Overlay



74°55'
74°54'
10 Feet Contour
Maximum Flood of Record
38°57'
38°57'
Lafayette St.
Cape May
Harbor
N
Washington St.
Pittsburgh Ave
Columbia Ave
Cape
May
New
Jersey Ave
Atlantic Ocean
38°56'
38°56'
Municipal Pier
CAPE MAY, N. J.
HAZARD ZONES
One Mile
74°55'
74°54'

Figure 10

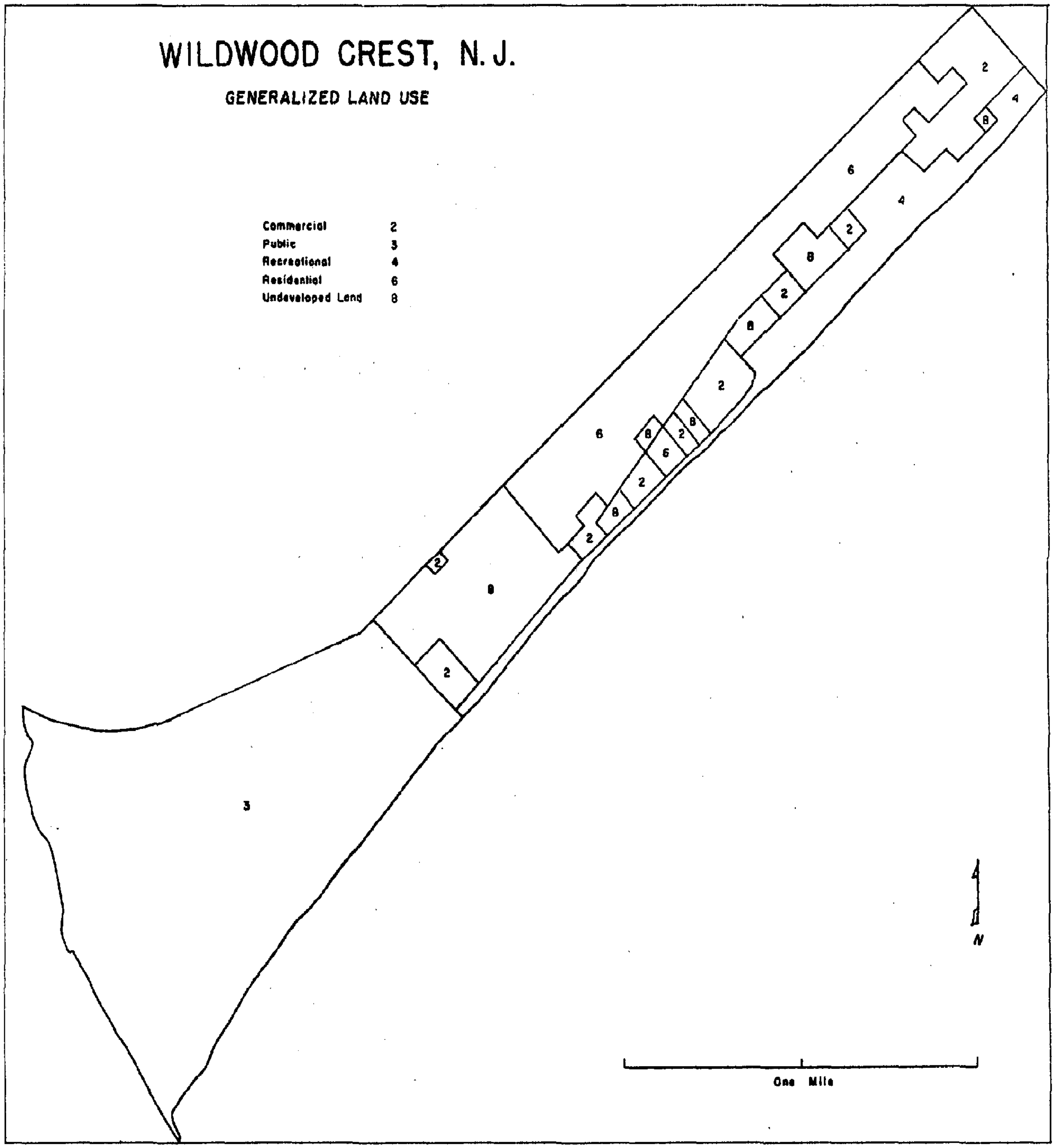


Figure 11 - Overlay

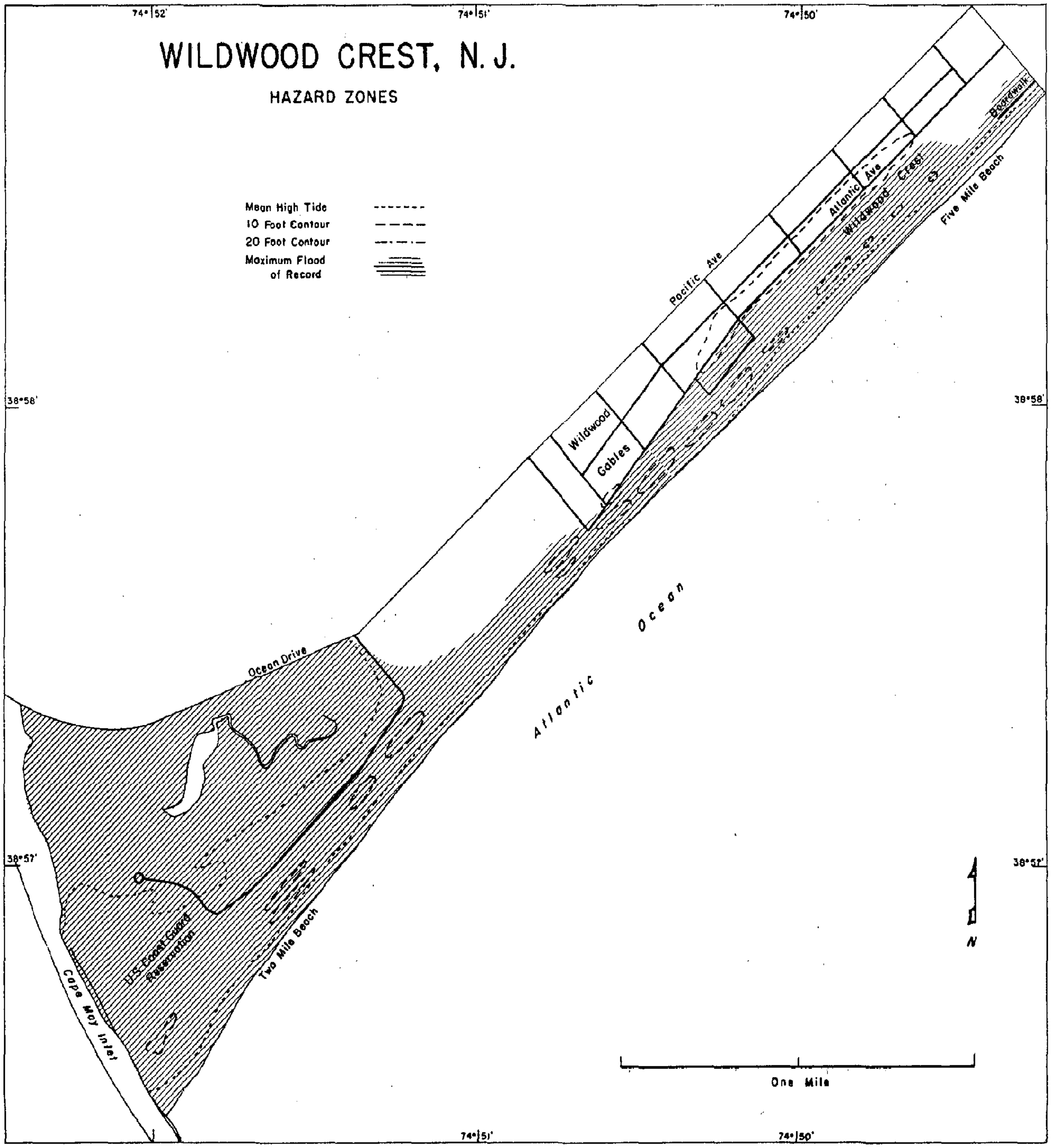

WILDWOOD CREST, N. J.
HAZARD ZONES
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record
74°52'
74°51'
74°50'
38°58'
38°57'
Pacific Ave
Atlantic Ave
Wildwood Crest
Wildwood
Gables
Boardwalk
Five Mile Beach
Atlantic Ocean
Ocean Drive
U.S. Coast Guard Reservation
Two Mile Beach
Cape May Inlet
N
One Mile

Figure 11

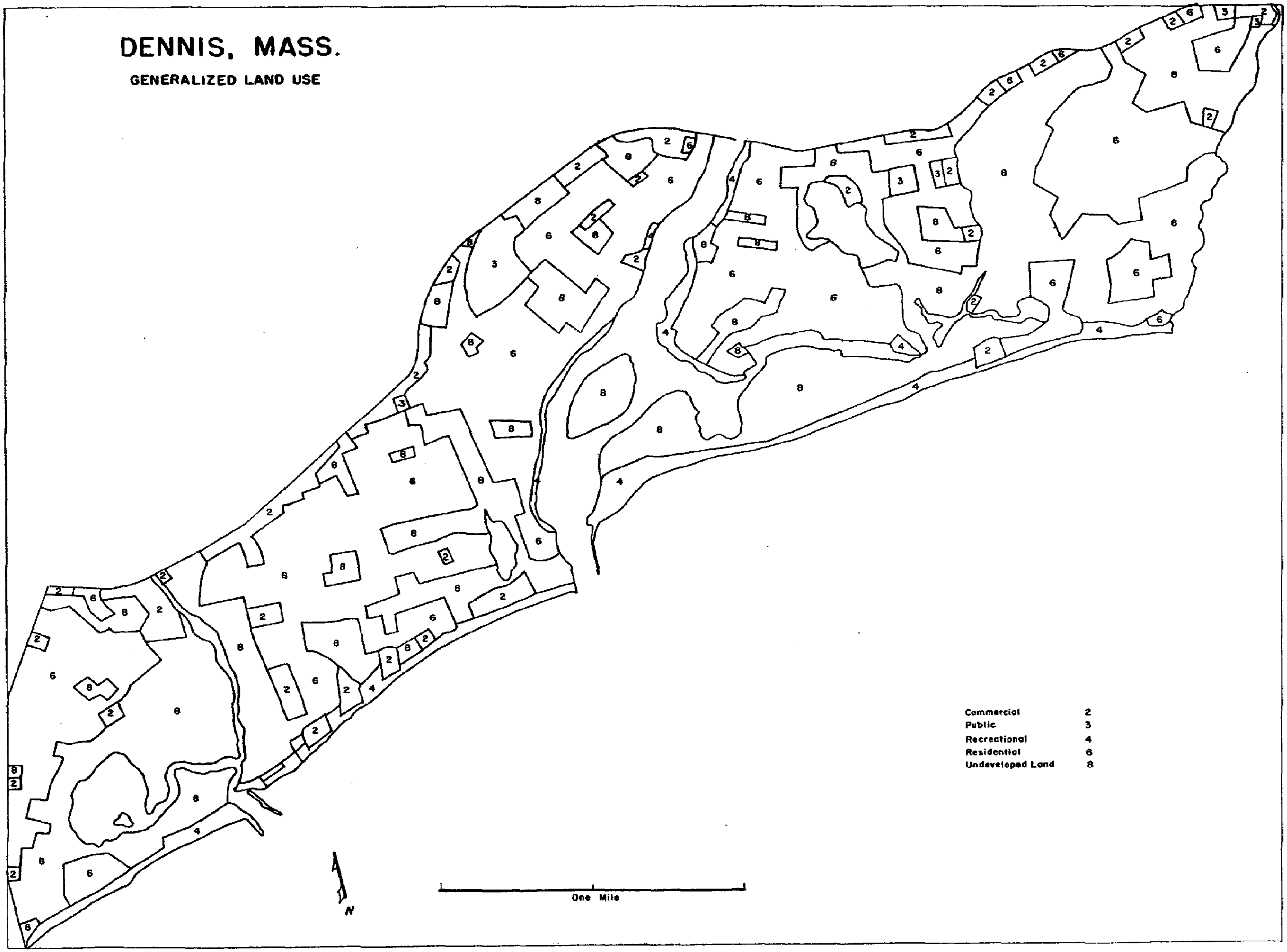


Figure 12 - Overlay

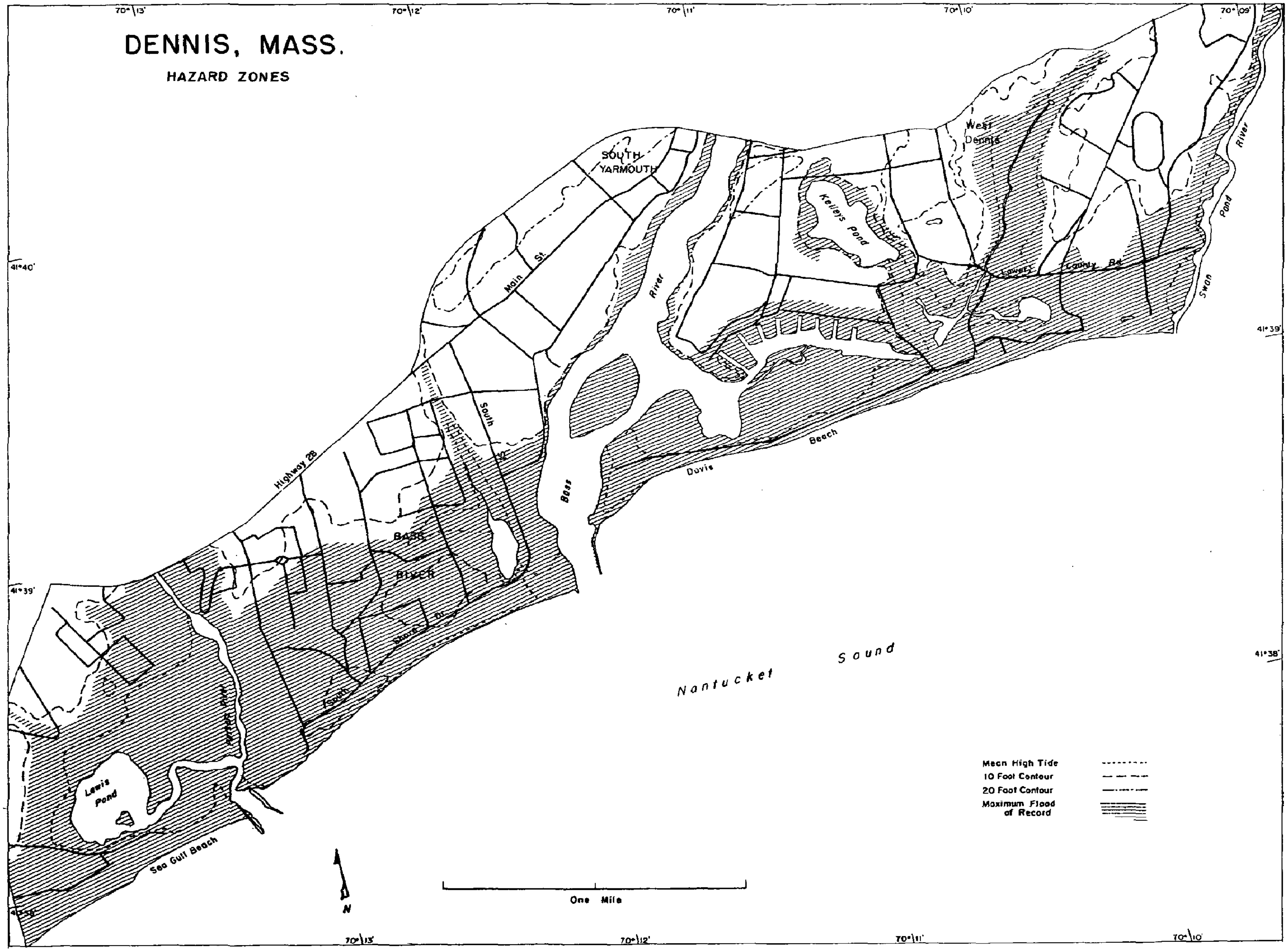

DENNIS, MASS.
HAZARD ZONES
70°13'
70°12'
70°11'
70°10'
70°09'
41°40'
41°39'
41°38'
SOUTH YARMOUTH
West Dennis
Kelleys Pond
Main St.
Highway 28
South St.
Bass River
Bass River
Lower County Rd.
Swan Pond River
Davis Beach
Nantucket Sound
Lewis Pond
Sea Gull Beach
N
One Mile
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record

Figure 12

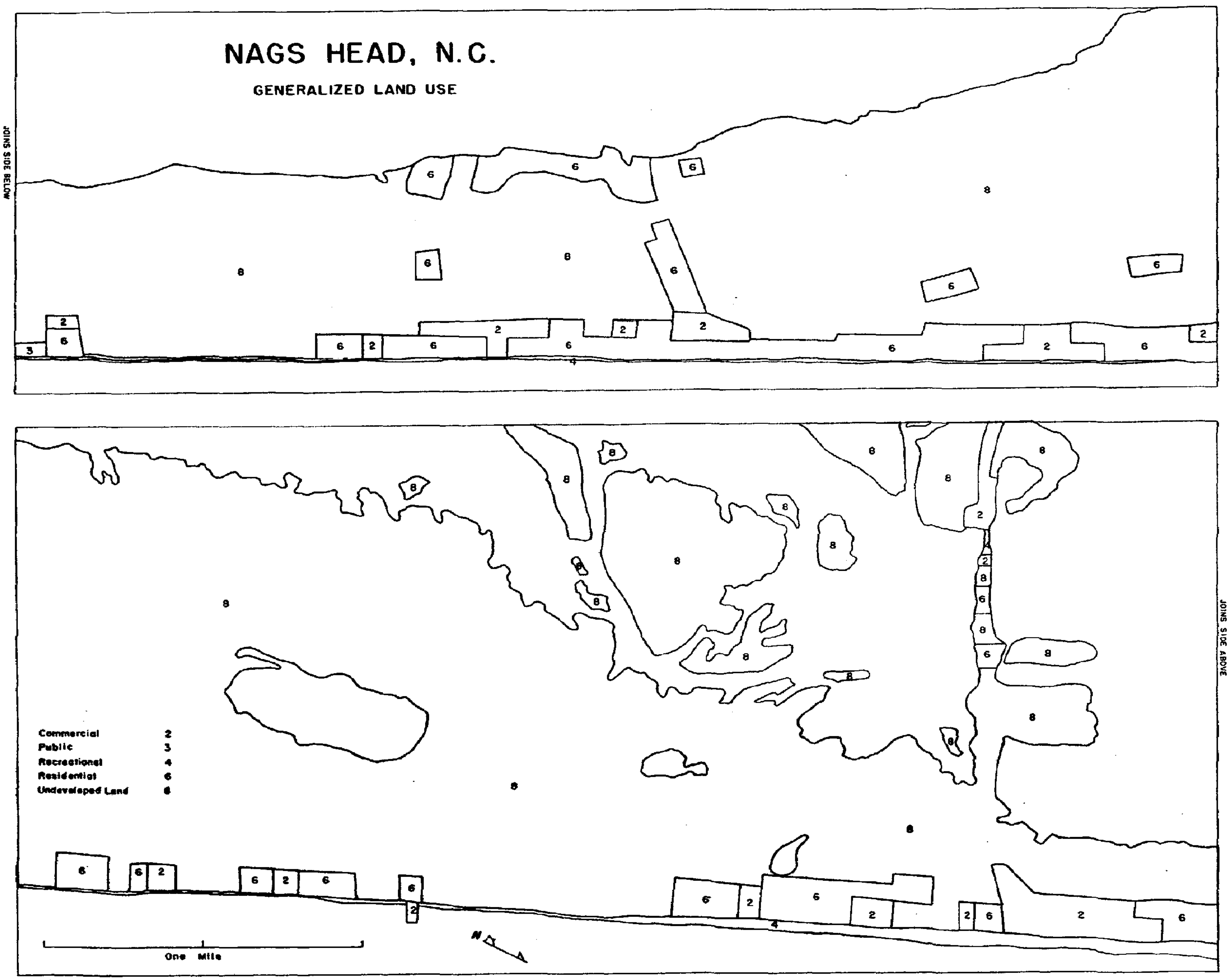


Figure 13 - Overlay

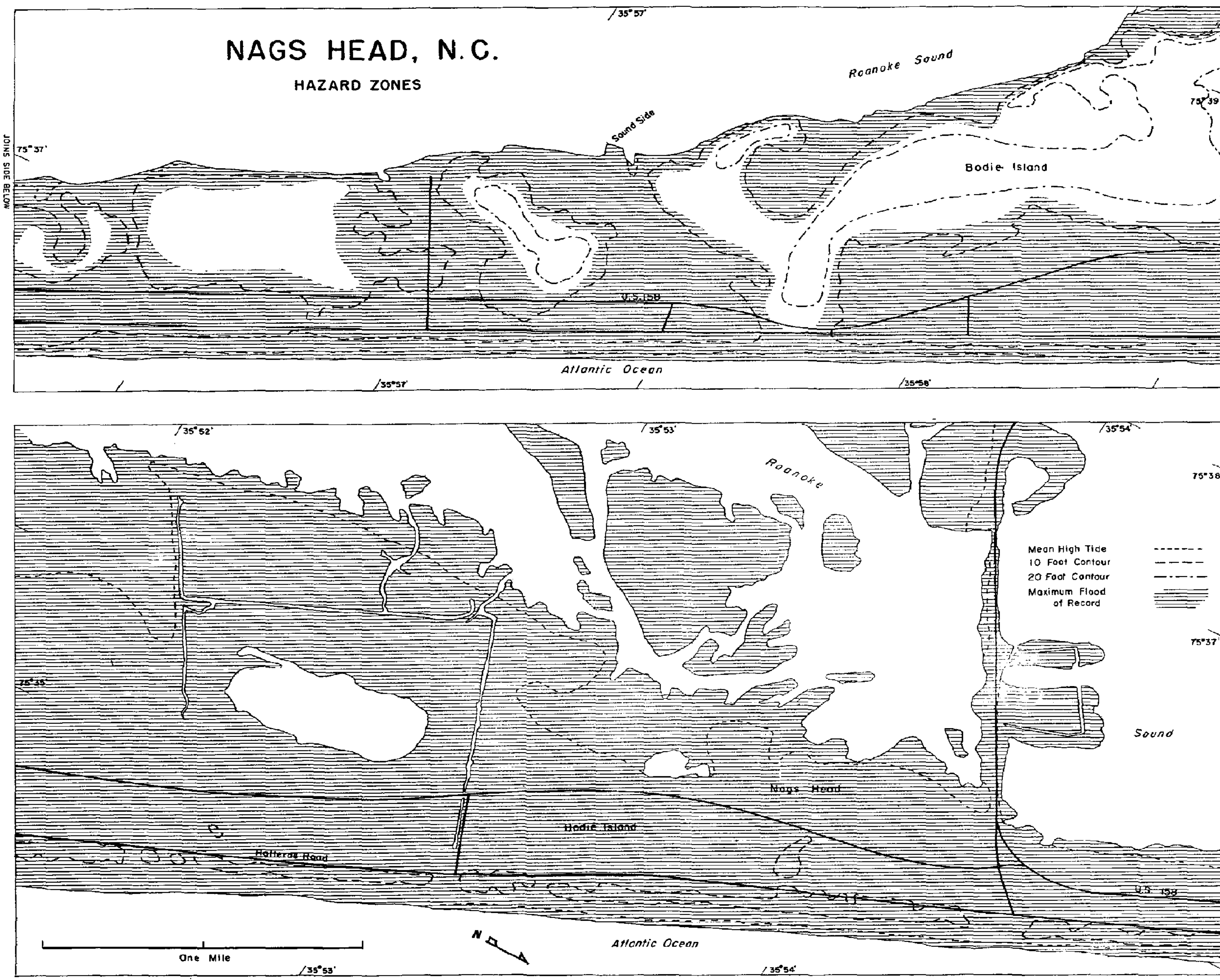

NAGS HEAD, N.C.
HAZARD ZONES
Roanoke Sound
Sound Side
Bodie Island
U.S. 158
Atlantic Ocean
JOINS SIDE BELOW
75°37'
75°39'
35°57'
35°58'
35°52'
35°53'
35°54'
75°38'
75°37'
75°35'
Roanoke
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record
JOINS SIDE ABOVE
Sound
Nags Head
Bodie Island
Hatteras Road
U.S. 158
Atlantic Ocean
One Mile
N

Figure 13

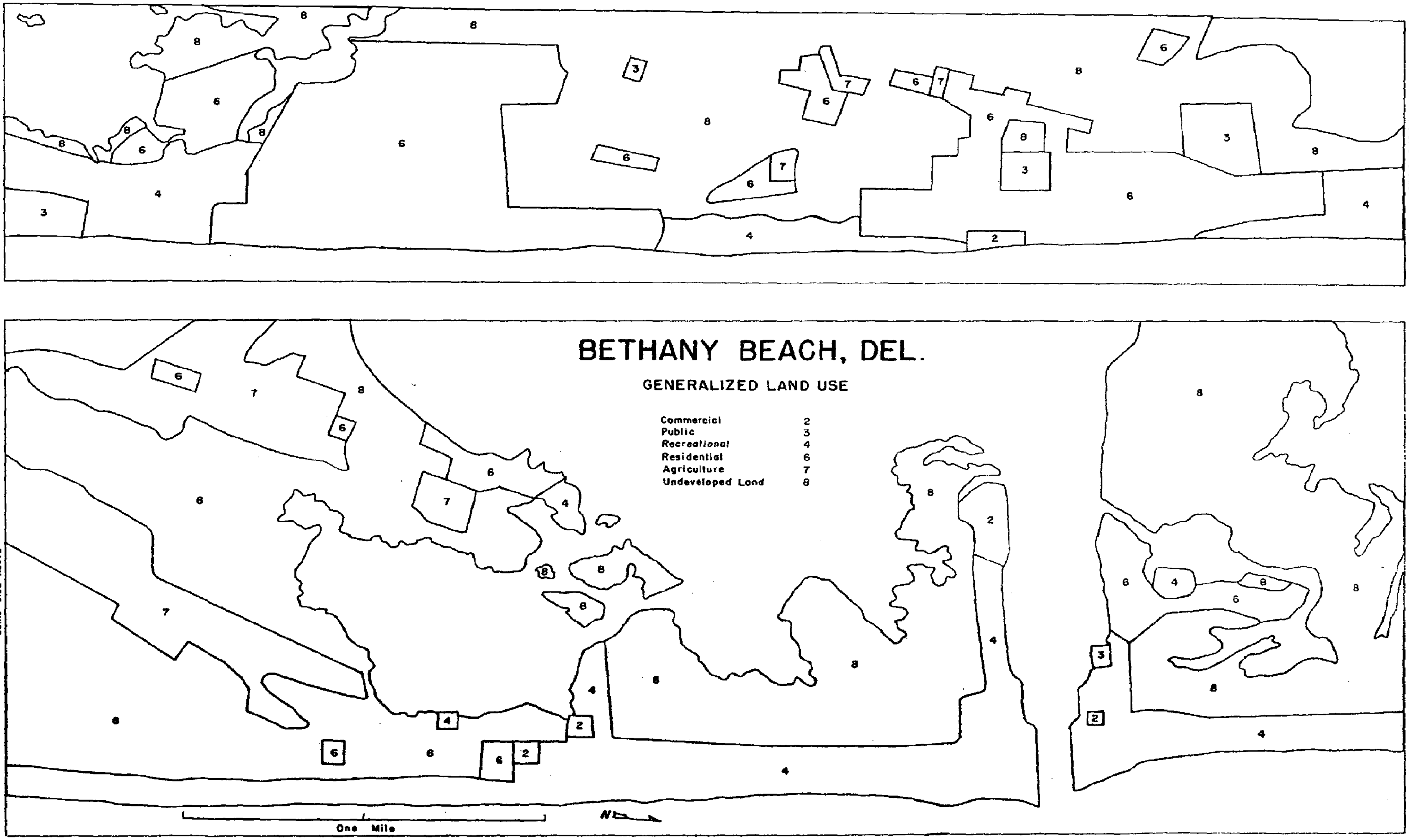


Figure 14 - Overlay

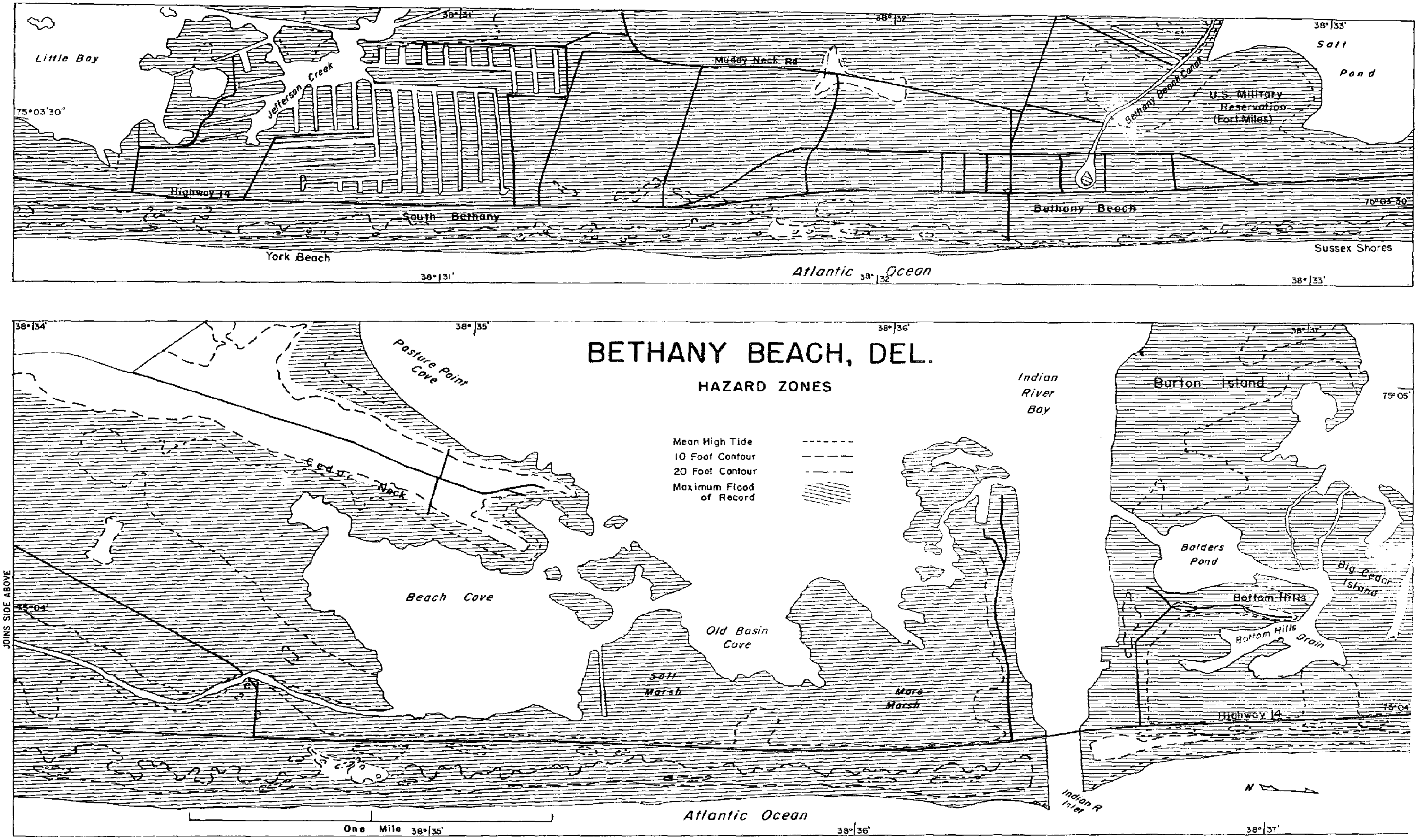

BETHANY BEACH, DEL.
HAZARD ZONES
Mean High Tide
10 Foot Contour
20 Foot Contour
Maximum Flood of Record
Little Bay
Jefferson Creek
Highway 14
South Bethany
York Beach
Muddy Neck Rd
Bethany Beach Canal
U.S. Military Reservation (Fort Miles)
Salt Pond
Bethany Beach
Sussex Shores
Atlantic Ocean
JOINS SIDE BELOW
JOINS SIDE ABOVE
Pasture Point Cove
Cedar Neck
Beach Cove
Old Basin Cove
Salt Marsh
Indian River Bay
Burton Island
Balders Pond
Big Cedar Island
Bottom Hills
Bottom Hills Drain
Highway 14
Indian R Inlet
One Mile
N
75°03'30"
75°04'
75°05'
38°31'
38°32'
38°33'
38°34'
38°35'
38°36'
38°37'

Figure 14

largely because of the strong opposition of the shore-front property owners. The opposition is primarily based on aesthetic grounds. The residents do not wish to have their view of the ocean obstructed or to lose ready access to the shore. The feeling of confidence engendered by partial protective measures may also be a factor in the rejection of the seawall proposal.

Other public adjustments include a recent town ordinance that the floor level of all new structures near the coast must be at least 12 feet above mean sea level.

Private adjustments include the construction of wooden bulkheads along the shore-front, as well as small stone groins and deposition of rip-rap. Shore residents also commonly move their cars to higher ground during hurricane warnings. A siren is sounded to give the warning and it also announces that the sea-front is restricted to residents only.

Future development. Fairfield has little potential for further recreational development. The shoreline is virtually inaccessible to the outsider. Most of it is being developed for private use with no easy public access. There are three public beaches, two of which are very heavily used, and their use is restricted. In the case of both public and private beaches little or no parking facilities are provided.

A new marina is presently under development at Ash Creek, but the fishing potential does not appear to be high and boating is mainly confined to the area's residents. The area has little prospect of growth into a resort community and is not likely to attract visitors from outside. Even if this were possible there is little indication that the present residents would want to see such development.

Fairfield increasingly functions as a dormitory suburb with commuters going to nearby Bridgeport or even as far as New York City. This study site provides an example of a densely settled urban shore inhabited largely by permanent residents who show little concern about flood and storm hazard. Both private and public adjustments have been made which help to reduce damage, but the area has inadequate protection against the really big and infrequent storm. In view of the rejection of the seawall proposal, flood damage can be expected to occur in the future but damage should only increase in proportion to the slow rise in value of sea-front property.

The Summer Shore

7. Hampton Beach, New Hampshire [1]

Hampton Beach is a summer resort community on the New Hampshire coast. The study site extends along 3.8 miles of shoreline from the Essex-Rockingham County line

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[1] Field work by Robert Arnold and Richard Hecock. We are indebted to the following persons who supplied information: Mr. Ray Goding, Mr. Bochner, Mr. William Elliott, and Mr. Carl Lougee.

at Seabrook Beach, north to Route 101E, which joins the coast at Hampton Beach. Included within the area are Seabrook Beach, Hampton Harbor Inlet, Hampton Beach, Great Boars Head and a large section of marshland behind the beach, drained by the Hampton and Blackwater Rivers. The area is 2,820 acres in size. (See figure 7 in the appendix.)

Physiography. This study site consists of two baymouth bars, backed by extensive tidal marshes, which connect with two rocky headlands representing outliers of the mainland.

A percentage breakdown of landform types shows 61 percent of the area in tidal marsh, 19 percent in baymouth bars and sandy beach, 15 percent that can be considered mainland, 1 percent in rocky headlands which are outliers of the mainland, and 4 percent in artificial fill.

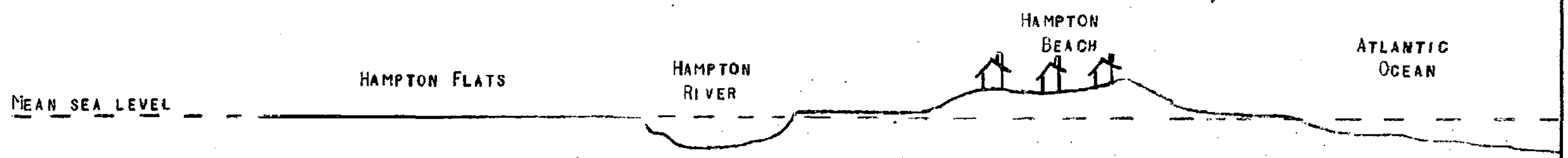
The marsh area behind Hampton and Seabrook baymouth bars consists of fine silts and clays covered by high marsh grasses. The 7-foot mean tidal range results in movement of large amounts of water in and out of Hampton and Blackwater Rivers through Hampton Harbor Inlet.

The baymouth bars average one-quarter of a mile in width. A 300- to 400-foot wide, gently sloping beach stretches along most of the seaward side. The sand bars are non-cliffed and regular in shape with low dunes behind the back-beach. Snow fences placed in 1930 at Hampton State Park have built up the dune height to 10 feet. Dune grasses are able to hold the sand quite well. Both baymouth bars are connected to rocky promontories. On the north, Great Boars Head is the control point for Hampton Beach and has contributed some of the material to build up this bar. Beckmans Point to the south is the control point for Seabrook Beach which has grown north. Some material for the beaches is derived from the rivers which enter the sea at Hampton Harbor Inlet, and some of the sand has as its source the thin glacial till which covers the bedrock on the promontories. A wave-cut marine platform, with a series of small coves, lies seaward of the rocky control points. It appears, therefore, that the shape and material which make up the baymouth bars are directly related to these more resistant headlands. The one hill in the study site is a 40-foot high drumlinoid which caps the bedrock of Great Boars Head. As these headlands are cut back by large storm waves the configuration of the bars will be influenced.

The mainland section of the study site consists of two small areas, one in the southwest corner of the study site and a large section in the northwest corner. Both these areas are gently rolling plains 20 to 30 feet above mean sea level. Bedrock close to the surface is covered by a thin veneer of glacial till. Sections of this seaboard lowland are under cultivation (See cross section, figure 2-7.)

Vegetation within the study site varies from grass in the low, nearly flat, tidal marshes to herbaceous plants, mixed broadleaf deciduous, and needle-leaf evergreen trees on the mainland. Only a small portion of the baymouth bars has dune grasses.

STUDY SITE NO. 7



	A	B	A
ZONE	BELOW MEAN HIGH TIDE, A FEW AREAS WITH FILL ABOVE MEAN HIGH TIDE	ABOVE MEAN HIGH TIDE, BUT BELOW 10 FEET	BELWO MEAN HIGH TIDE
GEOMORPHIC TYPE	FLAT TIDAL MARSHES WITH SILTS AND CLAYS. SOME MARSH FILLING	SAND BARRIER WITH A FEW LOW DUNES	COARSE SANDY TO GRAVEL BEACH WITH GENTLE GRADIENT
TYPE OF HAZARD	TIDAL INUNDATION AND FLOODING DURING SEVERE STORMS	FLOODING, SOME EROSION AND DAMAGE TO STRUCTURES	FLOODING AND EROSION
DEGREE OF HAZARD	MINOR	MODERATE	MODERATE
STRUCTURES	FEW	MANY	FEW
ADJUSTMENTS	NEW HOUSING DEVELOPMENTS BUILT ON FILL IN THE MARSH AREAS. NEW ROADS ACROSS THE MARSHES	SEA WALLS, SAND FENCES, AND SOME PROTECTION TO STRUCTURES	BREAKWATERS, AND JETTIES. PLANS TO PUMP SAND TO THE BEACHES

FIGURE 2-7. DIAGRAMMATIC CROSS SECTION, HAMPTON BEACH, NEW HAMPSHIRE

Storm hazard. The Hampton Beach study site has a high frequency of storms of all kinds but the degree of hazard is only moderate when compared with places such as Point Judith. Field observations estimate the flood of record to be about 10 feet above mean sea level. A Beach Erosion Control Report[1] places the record tide at 3.9 feet above mean high water which, when measured from mean sea level, gives an estimated flood of record of 8.7 feet. The following flood levels can be given from actual storm occurrences. Tides exceed mean high water by 1 foot or more on the average 107 times a year; by 2 feet or more 12 times a year; and by 3 feet or more, once every two years. The United States Weather Bureau's Storm Surge Warning Map[2] states that flooding of waterfront cottages begins at 7.5 feet above mean sea level and a section of the beach road in Salisbury, Massachusetts floods at 8 feet above mean sea level. Local observations of an exceptional spring tide of December 29, 1959, indicated a maximum height to be approximately 12.6 feet above mean low water or 8.6 feet above mean sea level.[3] A maximum storm tide height of between 8 and 9 feet above mean sea level appears to be accurate.

Marsh areas become flooded in winter with every strong northeast storm, but water piles up only with a strong west wind, against the inner side of the barrier bars and causes damage to structures. Without a beach or sand dunes to check the rise of water, these areas are only safe when structures are placed on fill at least 10 feet above mean sea level.

Flooding, beach erosion, and frontal structural damage are the main types of damage found at the Hampton Beach study site. Their occurrence is quite frequent with winter cyclonic disturbances which include the "northeasters." But severe structural damage and flooding is limited to the immediate coastal zone. At Rye Beach and Hampton Beach, 850 cottages were inundated by sea water during a northeaster in April, 1958.

By far the largest number of storms can be classified as "northeasters." The United States Weather Bureau at Boston, Massachusetts shows that 80 out of the 160 gales which occurred during the 75-year period, 1870-1945, were northeast gales.[4] These storms represent major disturbances, often of several days duration accompanied by rain or snow, high tides, shore inundation, and destructive wave and wind action.

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[1] U.S. Army Corps of Engineers, Beach Erosion Control Report on Cooperative Study of Hampton Beach, New Hampshire, U.S. Army Engineer New England Division, Boston, Mass., August 14, 1953, pp. 9-10.

[2] U.S. Department of Commerce, Weather Bureau, Storm Surge Warning Map, No. 2, August 1962.

[3] Hampton Municipal Development Authority, Marsh Reclamation Project Preliminary Plan for Project Area No. 1, Hampton, New Hampshire.

[4] Corps of Engineers, Shore of the State of New Hampshire, Beach Erosion Control Study, 87th Congress, 2nd Sess., House Doc. 416, May 21, 1952, pp. 16-17.

Settlement history. The town of Hampton traces its origins back to a plantation called Winnicumett in 1635 and remains today a compact New England town with a meeting-house green. But two miles from the town center is New Hampshire's "Happy Hampton", a major New England summer resort for many years.

Osgood's handbook for travellers in 1883, described the Hampton Beach Settlement of that time as follows:

> "Stages run from the station to Hampton Beach . . . Besides the hotels, there are many small summer cottages on and near the beach . . . From the vicinity of Boar's Head, a sandy beach extends S to Hampton River where many vessels were made in the colonial days. The river forms a safe harbor for coasters, though its entrance is fringed with rocks and shoals. Its clams are famous, and water-fowl formerly abounded, while the settlement of Hampton was due to the abundance of Salt Hay on its marshes."[1]

Today the harbor is heavily silted, but the recreational character of Hampton settlement is stronger than ever before. In 1952, over sixty percent of the assessed valuation of the entire town was classified as recreation property, and the percentage is probably larger today.

With a present town population below 3,000, Hampton will play host to crowds of more than 100,000 visitors on a single day.

Land use changes. There have been considerable changes in land use in the period since the first available air photograph coverage in 1952. Over five hundred new single-familiy residences have been added, many of them as homes for summer visitors. There has also been a substantial increase in the number of commercial structures. The increases have been both in the form of intensified use of previously developed areas and extensions into formerly undeveloped areas. Intensification of development has occurred at Seabrook where the number of cottages has almost doubled, and in the commercial strips along Ocean St. and Marsh Ave.

Extension has occurred by the reclamation of considerable marsh areas for residential and commercial development. It was not possible to define the extent of a maximum flood of record in the marsh area and the pattern of future flooding will in any case be quite different from the past due to reclamation of marshland. It is not known to what degree of hazard the new developments on the reclaimed marshland are subject. Land use changes are shown in the overlay to figure 7 (appendix), and recorded changes are given in table 2-7.

Adjustments to hazard. There is a relatively low level of concern about the storm hazard in Hampton Beach. This may reflect the lack of heavy damage in recent years.

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[1] New England: A Handbook for Travellers, Boston, James R. Osgood and Co., seventh ed., 1883, p. 262.

Table 2-7

Hampton Beach, New Hampshire

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures			No. Acres		
		1952	1963	% change	1952	1963	% change
A	8 Undeveloped	0	0	0	2035	2035	0
Tidal	Total	0	0	0	2035	2035	0
B	2 Commercial	25	39	+56	20	20	0
	4 Recreational	0	0	0	125	125	0
	6a Residential	434	617	+42	44	59	+34
	8 Undeveloped	0	0	0	40	23	-42
Tidal-10'	Total	459	657	+43	241	241	0
C	2 Commercial	477	482	+1	47	50	+6
	4 Recreational	5	5	0	31	31	0
	5a Recreational	0	0	0	14	33	+136
	6a Residential	793	1104	+39	162	167	+3
	8 Undeveloped	0	0	0	171	144	-16
10'-20'	Total	1285	1602	+25	433	433	0
D	2 Commercial	9	9	0	0	5	+400
	6a Residential	58	88	+52	14	28	+100
	7 Agricultural	3	3	0	14	14	0
	8 Undeveloped	0	0	0	68	49	-28
> 20'	Total	70	101	+44	106	106	0
F	2 Commercial	n.d.[2]	n.d.		10	10	0
	4 Recreational	n.d.	n.d.		158	158	0
	5a Recreational	n.d.	n.d.		3	3	0
	6a Residential	n.d.	n.d.		37	46	+24
	7 Agricultural	n.d.	n.d.		0	0	0
	8 Undeveloped	n.d.	n.d.		2120	2111	0
Flooded	Total	n.d.	n.d.		2332	2332	0
All Zones	2 Commercial	511	530	+4	67	75	+12
	3 Public	10	13	+30	16	18	+12
	4 Recreational	5	5	0	158	158	0
	5a Recreational	0	0	0	21	40	+90
	6a Residential	1285	1809	+41	220	254	+15
	7 Agricultural	3	3	0	19	19	0
	8 Undeveloped	0	0	0	2314	2251	-3
	Total	1814	2360	+30	2815	2815	0

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] n.d. -- No data.

There appears to be a widespread belief that small scale individual protection measures are sufficient to eliminate the danger.

Private action to reduce storm damage includes the construction of seawalls; the placing of rock rubble on the ocean side of dunes, the raising of structures on piles above the high water level; the filling of marshland to heights ranging from 1 foot to 4 feet; and the petitioning of public officials and legislators to provide more protection at public expense.

Public protection measures include a breakwater at Hampton Harbor Inlet, and a seawall along the front of Hampton Beach. Snow fences were placed along the shore at Hampton State Park in 1930 and these have helped to establish dunes up to heights of 10 feet. Other adjustments include a new road across the tidal flats behind Hampton Beach, which can be used as an escape route during severe storms. Plans are also in hand to pump sand for beach nourishment from Hampton Harbor Inlet to the beach north of Church Street. Several new jetties and groins are also planned.

Hampton Beach is well protected from frontal assault by storm waves. The safety of the recent marshland reclamation developments is more in doubt. Although private filling of the marsh up to 4 feet precedes building, there is a danger that the fill may not be high enough. Areas not filled high enough in the past have suffered flood damage when west winds pile water up against the lagoon side of the bar. To be safe the marshes need to be filled to a height of at least 10 feet above mean sea level.

Future development. Further development seems likely to be confined to additional marshland reclamation, since all other available land is in publicly-owned recreation areas or has already been developed. A controversy surrounds the future use of the marshlands since some people would like to see them kept as open space. Hampton Beach is an example of a highly seasonal resort area where expansion into low lying marshland provides the only opportunity for further growth. Reclamation of marshland appears likely to continue, but in the absence of knowledge about likely flood heights, and in the absence of building codes that specify a minimum amount of fill the trend of flood damage potential, while not clear at the present time, is probably in an upward direction.

8. Montauk, New York[1]

The second example of the summer shore type of development is the resort community of Montauk. The study site includes 8.4 miles of the coastline of Long Island and incorporates reaches of both the northern and the southern shores. The coastal zone extends from a point just east of the United States Coast Guard Reservation at Ditch Plains west of Napeague Beach. The study site includes two small sections of shoreline on the

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[1] Field work by Robert Gardula and Roger Kasperson. We are indebted to the following person who supplied information: Mr. John Craft.

north side of Montauk Peninsula which border on Block Island Sound. Small sections of Montauk Harbor and Napeague Harbor, a section of Hither Hills State Park, and several large fresh water ponds are included within this study site. The total area is approximately 3245 acres. (See figure 8 in the appendix.)

Physiography. Approximately 91 percent of the site is made up of irregular rolling hills and depressions with disorganized drainage patterns. The upland represents the eastern prong of one of two large terminal moraines which make up Long Island. The glacial deposits are estimated to be from 100 to 200 feet thick. The surface form of the glacial till is made up of irregular hills and depressions called kames and kettle holes. A number of lakes and bogs are found because water collects in the depressions. The elevation of most of the upland averages between 50 and 150 feet above sea level.

Several of the largest depressions have openings to the sea. Napeague Harbor represents one such depression. However, Fort Pond is now a brackish water pond because sand carried by the littoral currents has closed off the north and south outlets to the sea. During exceptionally high tides and very severe storms, water breaks through the sand barriers and at times raises the water level of Fort Pond as much as four feet.

Where the morainic hills come to the coast, wave-cut cliffs are found. At Napeague Beach a 100-to 200-foot wide beach backed by low coastal dunes protects the 50-to 60 foot high cliffs from severe erosion. But to the east the beach is narrower, and ocean waves, in winter and during storms, are able to reach the cliffs and are slowly eating them away.

The material which makes up the uplands is morainic material consisting of poorly consolidated boulder clays, gravels and sands. (See cross section, figure 2-8.) Some small sections of silt and clay surround the inland water bodies.

The second physiographic division making up about 5 percent of the study site consists of tidal and upland marshes. These marshes are found around Fort Pond, Fresh Pond, Montauk Harbor, and low poorly drained sections of the upland. The marshes around the large ponds are subject to occasional salt water flooding when waves cross over the barrier beaches. The upland marsh areas only fluctuate during heavy rains.

The third division, making up about 4 percent of the study site, consists of a beach zone along the Atlantic Ocean and around the larger bays and ponds. The width of most of the ocean beaches averages about 100 feet. However, in summer the beaches are wider, averaging 150-200 feet, while in winter, the waves cut back the beach and carry the material off the coast. Sand for the beach is derived mainly from the morainic cliffs which are 50 to 60 feet high at Montauk Point. Although sand is the predominant material making up the beaches, coarse gravels and occasionally boulders are moved along the beach from the cliffs. Only very narrow beaches border the ponds and bays. Three types of coastal configuration are found at this study site. Where cliffs occur, the beaches are narrow, irregular, and usually the beach gradient is steep. The beach near the Coast Guard Reservation is an example of this type. Along sections of the coast where cliffs do not border the ocean, beaches are long, straight, and have greater width. Napeague Beach is an example of this second type. Around the bays, lagoons, and ponds the coastline is crenate from the circular movement of currents. Beaches at these locations are very narrow or non-existant. The coastline of Montauk Harbor consists mostly of marsh grass.

The material making up this study site is predominantly morainic consisting of boulder clays, gravels, and sands. Silts and clays are found where salt marshes occur and in the ponds and lakes. Beaches are composed of fine sands except near the wave-cut cliffs.

Vegetation consists of grass and herbaceous plants on the rolling hills and mixed deciduous and coniferous trees in the more protected areas. Because of its marine location, this study site receives high winds and a great deal of fog and cloud cover. Many of the trees are stunted by the high winds. There are some sections, especially in Hither Hills State Park, where wind swept cliffs and slopes have almost no vegetation.

Storm hazard. This study site has only a moderate storm frequency and damage is low due to the favorable topographic conditions of the area. Beach erosion and frontal structural destruction are the two basic types of storm damage. Most of Montauk is well above the 20-foot contour level. However, the beach areas and sea cliffs are badly eroded during storms. Material eroded from the cliffs in winter is carried west along the coast and deposited on the beaches during the summer months.

Strong southeast winds blowing into deep low pressure areas moving across New England are at times destructive. During such storms dune leveling takes place and occasionally cottages are undermined. Away from the immediate coast, wind is the cause of most damage.

When waves and tides are large enough to cross the sand beaches, flooding will take place in the large ponds. During the 1938 and 1954 hurricanes, sea water broke through the beach and flooded Fort Pond inundating the buildings along the shore. During these same storms ankle deep flood waters covered the camping site at Hither Hills State Park.

Reports by the Corps of Engineers indicate that the flood of record for the Montauk Beach area is from 8.5 to 9.5 feet above mean sea level.[1] Interviews with local residents indicate an over-all range of from 5 to 10 feet for the highest water along the shore in the worst storms.

To the west of Montauk Beach, hazards increase rapidly as the hills decrease in height and long barrier bars form as a result of the westward movement of sand along the

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[1] Atlantic Coast of Long Island, New York: Fire Island Inlet to Montauk Point, Cooperative Beach Erosion Control and Interim Hurricane Study (Survey), U.S. Army Engineers District, New York, Corps of Engineers, New York 3, N.Y. July 1958.

STUDY SITE NO. 8

	A	B	C, D	B, C	A
Zone	Below mean high tide	Above mean high tide but below 10 feet	Above 10 feet and up to 100 feet	Above mean high tide but below 20 feet	Below mean high tide
Geomorphic Type	Bay and narrow beach	Sand barrier separating Fort Pond from the bay	Morainic uplands with rolling topography and scattered depressions. This upland projects into Fort Pond	Sand barrier, with a few dunes over 10 feet, separating Fort Pond from the ocean	Wide sandy beach
Type of Hazard	Flooding and some erosion of the beach	Tidal inundation only during very severe storms	None	Erosion of the dunes, flooding of Fort Pond during severe storms and some structural damage	Erosion of the beach
Degree of Hazard	Minor	Minor	None	Major only during severe storms	Severe
Structures	Few	Few	Numerous near the town	A few beach front structures	None
Adjustments	Few	Wharfs cause some protection	Few	Individual adjustments to hold dunes and protect structures	Several jetties exist. Plans for groins

Figure 2-8. Diagrammatic cross section, Montauk, New York

shore.[1] These low, sand barrier bars are much more susceptible to wave erosion and flooding.

Two of the most destructive storms were the 1938 and 1954 hurricanes. Hurricane Carol in 1954 caused extensive flooding of low areas. In some low areas, salt water was up to the glass windows of cottages, and the main highway to Montauk was cut off by tidal inundation during both storms.

Settlement history.[2] The first settlers of Montauk came in the early 1600's. By 1660 shore whaling made up a large part of Montauk's economy, with whaling stations employing many of the local citizens. This industry failed, however, in the latter 1800's when the demand for whale oil declined.

As early as the mid-1700's commercial fishing contributed substantially to the economy of the area, but reached its modern proportions in the 1850's. It was at this time that cottages called "fishing houses" were erected in fairly large numbers to accommodate the large influx of fishermen and their families. A small colony of these houses arose along the western shore of Fort Pond Bay.

By 1882 commercial fishing was firmly entrenched as a major industry and three major fishing stations were established. One was located on the eastern rim of Fort Pond Bay (Captain Tuthill's), one on the southern rim (Captain Wells'), and one west of what was called Railroad Dock at the easternmost tip of the Long Island Railroad (Captain Parsons'). Captain Wells' icehouse was demolished in the hurricane of 1938, as was Captain Tuthill's. These were replaced by refrigeration, a step toward modernization in the packing of fish. In 1942 the Navy took over Captain Parsons' property and his fishing operations came to an end. Of the earlier fishing operations only two remain, constituting the total of wholesale fisheries in Montauk at this time.

Coincident with the rise of commercial fishing in the 1800's was the development of Montauk's lobster fishery. This first began along the southern shore of Fort Pond Bay. Today, however, the demand for lobsters cannot be satisfied by the local catch alone, so lobsters are imported as well, some from as far away as Nova Scotia.

Montauk's commercial fishing reached its zenith several years ago and no longer ranks among the areas top three industries. Sportfishing, however, does, (along with the seasonal service industry and Republic Aerospace Corp.). During the height of the season, surf-casters alone number about 500 to 600 during any given 24-hour period.

Low accessibility delayed the rise of surf and boat sportfishing at Montauk. The modern era began during the 1920's with an increase in the number of automobiles and the

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[1] Final Report: The Protection and Preservation of the Atlantic Shore Front of the State of New York, Temporary State Commission on Protection and Preservation of the Atlantic Shore Front, July 1962.

[2] Based on field party notes assembled from various locally available sources.

improvement of highways. Also, in the early 1930's the Long Island Railroad inaugurated the "Montauk Fishermen's Special" with express trains to Montauk in the morning, returning to New York in the later afternoon. There were special boats for the patrons of the railroad as well. Through the 1940's the major sport-boat docks were located on Fort Pond Bay and the Railroad Dock.

In 1950, Montauk Harbor came into its own as a large number of docks and accommodations for fishermen sprang up. These expanded facilities attracted more charter and party boats to the area. A recent count shows more than 125 such boats available to the sportfishing public. Indications are that all of Northwest Cove between Star Island and the main peninsula will become one gigantic sportfishing harbor. Hundreds of privately owned and used boats also visit Montauk during the summer.

In the 1920's Carl G. Fisher, who initially developed Miami Beach came to Montauk in an attempt to duplicate his previous success. He made Lake Montauk (a fresh water body) a part of the sea as a first step toward making Montauk a competitor of New York City for ocean-going vessels, but died before his dream could be realized. In addition he built a beach club and hotel (Montauk Manor), and a 7-story headquarters building (the tallest building in Suffolk county) in the center of the village. This building now serves as headquarters for the Montauk Beach Co., successors to Fisher, and the main developing agency in the area since 1927.

The first motel in the area was built in 1950 and was shortly followed by a number of such establishments along the ocean-front.

Land use changes. There has been a steady growth of both residential and commercial buildings in the period since 1955. There are thirty new commercial buildings, providing mostly services for the summer visitors, and nearly one hundred new single family residences, many of them summer homes for visitors from the New York City area. A new subdivision has been started in the area south of Lake Montauk. Most of the new developments are in the higher areas and well beyond the reach of flood waters.

The pattern of land use is shown in the overlay to figure 8 (appendix). Recorded land use changes are shown in table 2-8.

Adjustments to hazard. In view of the low level of storm damage, the perception of the hazard is remarkably high in Montauk, in the flood hazard area itself. Due to the topographic characteristics of the study site the hazard zone is very limited in extent,and concern about the hazard outside this zone is minimal.

In the high hazard areas, particular concern was given to the problem of erosion and the effect that this was having on the danger of flooding. In the center, many commercial establishments expressed concern over the erosion of the dunes which afforded natural protection. In the strip of residences along the Bay side, a bitter issue was the dredging of sand just offshore from the beach, which residents thought substantially increased storm hazard. Although they banded together and opposed the dredging, it continued to go on at the time of the field work.

Table 2-8

Montauk, New York

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures 1955	No. Structures 1963	No. Structures % change	No. Acres 1955	No. Acres 1963	No. Acres % change
A	4 Recreational	0	0	0	8	8	0
	8 Undeveloped	0	0	0	54	54	0
Tidal	Total	0	0	0	63	63	0
B	1 Industrial	17	17	0	84	84	0
	2 Commercial	14	18	+29	9	14	+56
	4 Recreational	0	0	0	82	82	0
	5 Recreational	0	0	0	77	77	0
	6a Residential	49	60	+22	14	16	+14
	8 Undeveloped	0	0	0	144	137	-5
Tidal-10'	Total	80	95	+19	410	410	0
C	2 Commercial	89	109	+22	67	70	+4
	4 Recreational	0	0	0	78	78	0
	6a Residential	45	64	+42	25	34	+36
	8 Undeveloped	0	0	0	257	243	-5
10'-20'	Total	139	178	+28	437	437	0
D	2 Commercial	56	62	+11	63	69	+10
	4 Recreational	0	0	0	704	704	0
	6a Residential	156	219	+40	97	128	+32
	6b Residential	58	58	0	44	49	+11
	8 Undeveloped	0	0	0	1417	1381	-2
> 20'	Total	273	343	+26	2328	2335	0
F	1 Industrial	16	16	0	42	42	0
	2 Commercial	14	14	0	11	11	0
	4 Recreational	0	0	0	98	98	0
	5a Recreational	0	0	0	77	77	0
	6a Residential	8	8	0	6	6	0
	8 Undeveloped	0	0	0	47	47	0
Flooded	Total	38	38	0	281	281	0
All Zones	1 Industrial	17	17	0	84	84	0
	2 Commercial	159	189	+19	139	153	+10
	3 Public	3	4	+33	3	4	+33
	4 Recreational	0	0	0	872	872	0
	5a Recreational	0	0	0	77	77	0
	6a Residential	250	343	+37	137	179	+31
	6b Residential	63	63	0	54	61	+13
	8 Undeveloped	0	0	0	1872	1815	-3
	Total	492	616	+25	3238	3245	0

[1] Minor land uses omitted and total may exceed land uses enumerated.

Private adjustments to hazard include many attempts to check erosion by dumping boulders, bed springs and timber at the base of the cliffs. Snow fences are used to build sand dunes. Some buildings in the hazard area are erected on piles and at the Surf Club it is common practice to open the main doors so that storm water may run through the building into the pool.

Public preparations for storms include provision for the evacuation of people to higher ground, and the stationing of half of Montauk's fire equipment west of Fort Pond. In this way the area has fire protection and equipment for rescue operations, should it be cut off from the rest of the town.

Future development. Montauk is a scenically attractive area that is rather remote from large centers of population. Largely for this reason its rate of growth has been modest. The area has a high potential for further recreation development, however. There are over thirty miles of shoreline at the eastern end of Long Island that are sparcely used. Of the 1,800 acres at Hither Hills State Park only 75 have been developed. Good beaches and sportfishing provide a variety of recreational opportunities.

In Montauk the growth has been rather slow since 1952. The area clearly has great potential for recreational development, however, and this may come soon. Most of the development is likely to occur outside the major hazard zones and a substantial increase in damage potential appears unlikely.

9. Sandy Hook, New Jersey[1]

The Sandy Hook study site includes part of the densely developed community of Highlands and the summer shore community of Sea Bright. Sandy Hook is located at the northern extremity of the New Jersey Atlantic shoreline.

It faces New York City across New York Bay. The study site occupies 8.3 miles of the coastline between the Coast Guard Station in Galilee, north of Monmouth Beach, to the entrance of Fort Hancock Military Reservation on Sandy Hook spit. The study site also includes two small sections of the mainland, the extreme eastern parts of Highlands and Rumson peninsulas. The total area of this study site is approximately 1065 acres. (See figure 9 in the appendix.)

Physiography. Beach, marsh, and bluff are the three main physiographic types in this area. About 74 percent consists of the southern end of a long, narrow, barrier bar which at its northern end becomes the complex recurved spit of Sandy Hook.[2] The sandy

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[1] Field work by Robert Gardula and Roger Kasperson. We are indebted to the following persons who supplied information: Mr. Richard L. Riker, Mr. H. W. Boud, and Mr. Jerry Welch.

[2] A. K. Lobeck, Things Maps Don't Tell Us. MacMillan and Co., New York, 1958, pp. 32-33.

beach on the seaward side of this spit averages less than 200 feet wide at mean low water. Only in the northern part of the study site does the beach become 300 to 400 feet wide.

Dunes and vegetation found within the study site occur only in the new state park which formerly was part of Fort Hancock Military Reservation. Here are preserved some of the largest and oldest holly trees in the United States. Dune grasses, low shrubs and cactus help hold the sand around the low 5- to 10-foot high dunes.

Approximately 12 percent of the study site consists of tidal marshes and flats. The features are found mainly on the landward side of the barrier island and at the mouths of the Navesink and Shrewsbury Rivers which flow to Sandy Hook Bay. In places, sections of these marshes, all of which lie less than 10 feet above sea level, are filled in by marinas and housing developments.

The third physiographic division is the mainland, making up 14 percent of the study area. The small sections of mainland included in the study site are the extreme eastern sections of two long necks which are separated by the drowned Navesink and Shrewsbury Rivers. Although most of this division consists of flat land underlain by Cretaceous and Tertiary gravels and marls, the seaward side of Navesink Highlands represents the inner Tertiary cuesta of the coastal plan and has 200-foot high cliffs. These cliffs over the years have been cut back by the sea, but today they are protected by the barrier bar. (See cross section, figure 2-9.)

Materials within the study site include sand and some silt on the barrier bar and spits. Soft muds and clays occur in the tidal lagoons and around the river mouths. Cretaceous and Tertiary gravels, marls, and clays are found on the mainland.

Storm hazard. Although the storm frequency in the vicinity of the study site is moderate, damage has been heavy in the recent times. The exact height of the flood of record is difficult to establish. The Corps of Engineers Reports[1] and interviews with the local residents estimate a flood record from 8 to 10 feet above mean water. Since nearly 86 percent of this study site is below the 10-foot contour, this study site has been, and will continue to be, subject to extensive flooding and damage from large storm waves and unusually high tides.

Sandy Hook spit has the highest degree of hazard. In severe storms such as that of March 6-7, 1962, the unprotected sections of Sandy Hook were breached in 11 places separating the bar into a number of flooded islands. The sections breached were in the northern part of the study site where a new state park is being developed.

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[1] Shore of New Jersey from Sandy Hook to Barnegat Inlet, Beach Erosion Control Study, 84th Congress, 2nd Session, House Doc. No. 361, Govt. Printing Office, Washington, 1957, pp. 17-20 and Shore of New Jersey from Sandy Hook to Barnegat Inlet, 85th Congress, 2nd Session, House Doc. No. 332, Washington, 1958, pp. 15-16 and appendices.

Flooding of property on the Atlantic side of the bar is usually confined to low areas and basements when water breaks over the seawall that protects most of the bar. On the lagoon side of the barier bar marinas receive heavy losses to dock facilities and boats during severe storms. Without the protection of the seawall the barrier bar would be subject to occasional complete separation as new inlets are cut. Both the ocean and the rivers have cut through the sand barrier several times. The Shrewsbury River, which now turns north and flows along the inner side of the barrier island to Sandy Hook Bay, broke through the barrier beach in the winters of 1777-1778, 1830-1831, and 1895.

Headland sections of the mainland receive little damage because the 10-foot seawall, the barrier beach, and the narrow lagoon protect the mainland areas from sea attack.

Settlement History.[1] As recently as 400 years ago, the barrier sand bar which is now Sea Bright and Sandy Hook was practically non-existent. The sand bar was then connected to Highlands and was very small. Within the past 200 years, the peninsula has been separated from the mainland on three separate occasions to form an island. The Shrewsbury River broke through the peninsula in the winters of 1777-1778, 1830-1831, and in 1895-1896 -- and in each case it took from 15 to 20 years to close the openings. Map studies indicate that the breaks did not occur in the same location each time. In the late 17th and early 18th centuries, the Hook was connected directly to Highlands, a fact verified in a map of 1777. Since then, geologic changes have made Sandy Hook a part of the barrier sand bar along the coast.

The Sandy Hook Light was erected in 1764 and apparently was a major cause of the present "clam-like" shape of the Hook. The light was originally built at the water's edge, but today is separated from the water by 500 yards of beach and is about 1-1/4 miles from the tip of the point. As one observer noted in 1958, "Sandy Hook is visible evidence of where Long Branch's beach had fled" Since 1870, openings to the ocean have been closed and much of the beach protected by a seawall.

Aside from the pre-European population, settlement in the study area began when Governor Nichols issued a proclamation in the fall of 1665 authorizing people to form a settlement at Portland Poynt (now Rumson and Highlands) Early settlement in the area has traditionally rested upon two chief occupations -- maritime activities (especially fishing) and truck farming. Clamming also became an important source of income during this early period. The families which migrated to Highlands and Rumson during this period settled in compact villages and not in the common rural homestead pattern of settlement.

Sea Bright differs from Rumson and Highlands in that it was a summer resort from its very inception. Originally, it was a little fishing village called Nauvoo, but always spoken of as "the huts," for the first houses were little else since the men only lived there during the summer. Even at this early point, there may have been some local adjustment to storm hazard because the structures were built against a "high bank covered with beach plum bushes."

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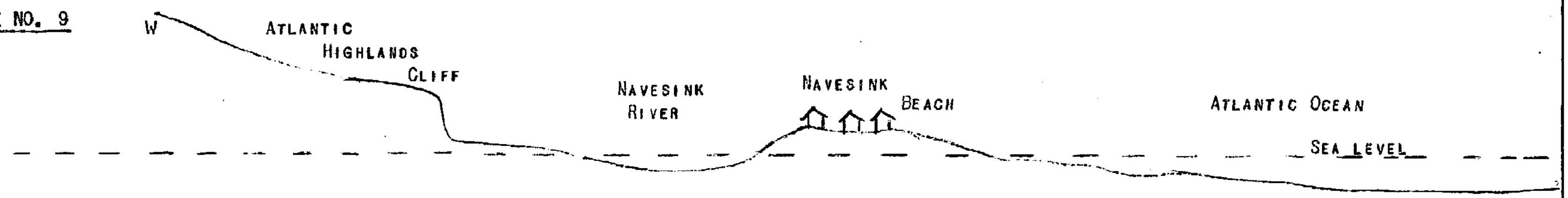
[1] Based on field party notes assembled from various locally available sources.

STUDY SITE NO. 9



	D	B, C	A	B	A
ZONE	ABOVE THE 20-FOOT CONTOUR	MEAN HIGH TIDE TO 20-FOOT CONTOUR	BELOW MEAN HIGH TIDE	ABOVE MEAN HIGH TIDE, BUT BELOW 10 FEET	BELOW MEAN HIGH TIDE
GEOMORPHIC TYPE	UPLANDS 200 FEET ABOVE SEA LEVEL	FOOT OF THE HILLS	TIDAL CHANNEL	SANDY BARRIER BAR	NARROW SAND BEACH, GENTLE GRADIENT
TYPE OF HAZARD	NO FLOOD HAZARD	LOW AREAS SUBJECT TO FLOODING	FLOODED AT HIGH TIDE	WAVE SPRAY OVER BULKHEAD	BEACH SUBJECT TO FLOODING AND EROSION DURING STORMS
DEGREE OF HAZARD	NONE	MINOR	DAILY INUNDATION	SOME HAZARD FROM EROSION	SEVERE HAZARD
STRUCTURES	FEW	MANY, TOWN OF HIGHLANDS	FEW	MANY SUMMER HOMES, MOTELS	FEW
ADJUSTMENTS	FEW	MARINA TO PROTECT BOATS	FEW	A 10-FOOT WALL ALONG MOST OF THE STUDY SITE. MANY INDIVIDUAL ADJUSTMENTS TO PROTECT STRUCTURES	BEACH FILLING, GROINS AND JETTIES

FIGURE 2-9. DIAGRAMMATIC CROSS SECTION, SANDY HOOK, NEW JERSEY

The first permanent residential structure in Sea Bright was built in 1869. However, a bad storm in 1915 undermined the beach near the house and it was moved across the river on barges and located in Rumson. Much of the early growth in the area is attributable to the transshipment business of Sandy Hook. As early as 1759 Sandy Hook was the terminal for regular coach lines running from Camden through Mount Holly, Shrewsbury, and Middletown. Passengers disembarked at Sandy Hook and completed the trip to New York by boat. The New Jersey Central Railroad route north from Long Branch used the same system. Trains ran to Sandy Hook and then a boat was taken to New York. The line was originally constructed along a narrow coastal strip in 1865, and maintained until 1946. The railroad has been instrumental in the past for the construction of the sea wall in this area, as during World War II when protection was needed for ammunition trains running out to Fort Hancock on Sandy Hook. Sandy Hook was purchased by the Federal Government in 1816. Fort Hancock was constructed from 1861-1866.

Sea Bright is now typical of the summer shore type of development. The whole bar is occupied by residences (some seasonal, some permanent), motels, and hotels.

Land use changes. The pattern of development has not changed greatly over the past 20 years. The most significant change has been the conversion of approximately 460 acres of undeveloped land into the Sandy Hook State Park. Accompanying the establishment of the state park has been the addition of several structures serving as bathhouses, refreshment stand, and restrooms. In Highlands the construction of a combination marina and restaurant was the only change detected.

Although the number of structures in Sea Bright has remained approximately the same, the uses to which some of the buildings are put has changed. A common development is for the former large single-family residences to be converted to guest houses. As a result many acres of beach which were formerly private with no public access are now open to visitors staying in guest houses.

Elsewhere on the barrier bar there has been an increase of single-family residences, filling up the only remaining undeveloped land. Many of the approximately twenty new residences are in the flood hazard area. The pattern of land use is shown in the overlay to figure 9 (appendix). Recorded land use changes are shown in table 2-9.

Adjustments to hazard. There is a high degree of awareness of storm hazard in the Sandy Hook area. This is especially true among the residents in Sea Bright and other parts of the barrier bar. Associated with this awareness is a high rate of adoption of private adjustments. These include construction of small seawalls, concrete aprons and bulkheads. Other respondents reported using sandbags to keep out sea water. Evacuation or preparing to evacuate is a common adjustment. Many residents also remove cars and other items of value from the hazard area. One commercial establishment reported the construction of a warehouse in a nearby town to which merchandise could be removed. Another respondent had an iron door to keep water out of his property. At least three houses in Highlands have been elevated several feet on new foundations.

Table 2-9

Sandy Hook, New Jersey

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures 1940	1947	% change	1963	% change	No. Acres 1940	1947	% change	1963	% change
A	4 Recreational	0	0	0	0	0	21	21	0	21	0
	8 Undeveloped	0	0	0	0	0	89	89	0	89	0
Tidal	Total	0	0	0	0	0	110	110	0	110	0
B	2 Commercial	46	51	+11	61	+20	31	26	-16	26	0
	3 Public	1	10	+900	21	+110	0	16	na[2]	33	+106
	4 Recreational	-	-		-		2	436	+21700	429	-2
	5b Recreational	-	-		-		53	5	-91	12	+140
	6a Residential	520	548	+5	557	+2	105	100	-5	100	0
	8 Undeveloped	-	-		-		586	183	-69	166	-9
Tidal-10'	Total	588	630	+7	659	+5	811	811	0	811	0
C	6a Residential	37	28	-24	32	+14	0	0	0	0	0
	6b Residential	11	11	0	13	+18	42	42	0	42	0
	8 Undeveloped	0	0	0	0	0	52	33	-36	33	0
10'-20'	Total	49	42	-14	51	+21	104	104	0	104	0
D	6a Residential	18	22	+22	35	+59	4	4	0	4	0
	8 Undeveloped	0	0	0	0	0	8	8	0	8	0
> 20'	Total	23	27	+17	40	+48	40	40	0	40	0
F	2 Commercial	46	51	+11	61	+20	29	26	-10	26	0
	5b Recreational	0	0	0	0	0	53	12	-77	12	0
	6a Residential	500	534	+7	540	+1	102	97	-5	97	0
	8 Undeveloped	0	0	0	0	0	473	174	-63	166	-5
Flooded	Total	563	605	+8	624	+3	681	681	0	681	0
All	2 Commercial	47	52	+11	62	+19	31	26	-16	26	0
Zones	3 Public	1	12	+1100	26	+117	14	28	+100	45	+61
	4 Recreational	0	0	0	0	0	23	476	+1970	469	-2
	5a Recreational	0	0	0	3	na	8	17	+112	17	0
	5b Recreational	0	0	0	0	0	49	5	-90	12	+140
	6a Residential	575	598	+4	624	+4	109	104	-5	104	0
	6b Residential	37	37	0	35	-5	96	96	0	96	0
	8 Undeveloped	0	0	0	0	0	735	313	-57	296	-5
	Total	660	699	+6	750	+7	1065	1065	0	1065	0

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] na -- Calculation not appropriate.

The major adjustment at Sandy Hook, however, is the ten-foot high seawall built to protect property behind the narrow beach. In severe storms waves can still top this wall. The wall extends from Sea Bright north to the southern boundary of the State Park. Another major adjustment is the construction of jetties which appear to be effective in reducing storm damage. Jetties are also favored by a number of inhabitants for their beach building qualities. The number of jetties could be increased but reluctance on the part of the Federal Government to subsidize these works was often cited as the main obstacle to their construction.

Future developments. The area comprises three quite distinctive settlement units. Highlands is an old compact and densely settled area consisting mostly of deteriorating timber frame structures on closely spaced lots. It is suffering from a continuation of urban blight and repeated flood damage. Though advertising itself as "the striper capital of the world" its attraction as a recreational area is very limited. Large scale urban renewal seems unlikely in the near future.

Rumson is quite different. Here is a more wealthy area with large homes on large lots. It is primarily for permanent residents who are likely to oppose any drastic change. It has only a narrow coastal strip and recreational potential is strictly limited.

Sea Bright and its extension up the barrier bar is the recreational center. Its importance stems in part from its proximity to New York City. It is the first real beach south of the city comparable with Jones Beach on Long Island. The area offers boating and fishing and the breakers and surf are a great attraction at the State Park. The bar itself is now fully developed.

Future development will be restricted to intensification of the present land uses. High rise building may come to replace present two story guest houses, hotels, and motels. Some commercial interests believe themselves to be on the threshold of rapid development. They foresee the growth of high rise apartments, yacht clubs, and beach clubs, and rapid conversion of residential land to commercial uses. Others are more conservative and think that the area is already fully developed.

Sandy Hook is an example of a densely developed summer shore. Storm hazard is high and there is a wide range of adjustments to flood. Flood damage potential is not likely to rise rapidly, but may increase as the value of seafront property rises and as the area becomes more like an urban than a summer shore.

10. Cape May, New Jersey[1]

Cape May is an old, fashionable resort at the extreme southeastern tip of the New Jersey shoreline facing Cape Henlopen across the mouth of Delaware Bay. The study area

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[1] Field work by Robert Arnold and Richard Hecock. We are indebted to the following persons who supplied information: Mr. James Byington, Mr. Jack Sweitzer, and Mr. Leland Sanford.

extends from Washington Street in the city of Cape May east to the United States Coast Guard Receiving Center on Sewell Point, and goes inland to include the dock basin at Cape May harbor. The area comprises 698 acres. (See figure 10 in the appendix.)

Physiography. Only about 2 percent of the study area can be classified as beach. The beach zone is only 1.6 miles long, and in places is not even a true beach. The gradient of the coast offshore is not as gentle as at Wildwood Crest and as a result there is more beach cutting. The few remaining beaches have been protected by man-made groins and much of the present beach consists of fill. After the March, 1962 storm, new seawalls were constructed of concrete, rock rubble, and steel behind the back beach. Low dunes are found only at the eastern end of the study site.

Approximately 88 percent of the Cape May study area is part of a low coastal plain, with an average elevation below 10 feet. One small section in the center of the site rises above 10 feet. Although most of this plain is flat a few small water filled depressions dot the landscape. Materials making up the mainland consist of a thin veneer of sand overlying coarse Pleistocene gravels.

The northern part of the Cape May study site borders on Cape May harbor. This harbor connects with the Cape May Canal which gives a protected route for small boats traveling between the NewJersey inland coastal waterway and Delaware Bay. Several marinas have been built on fill along the south side of the harbor. This fill makes up about 9 percent of the study site. Extensive tidal marshes surround much of Cape May harbor but only 1 percent of the Cape May study site is in this category.

The unpopulated sections of the study site are covered with a forest of mixed broadleaf deciduous trees, mainly oaks; and nettleleaf evergreen trees, mainly the Jersey scrub pine. Shrubs and grasses grow well in the low moist areas. (See cross section, figure 2-10.)

Storm hazard. In spite of a relatively low storm frequency, Cape May has suffered heavy damage in the recent past, especially from the storm of March, 1962. Battering waves have eroded and will continue to erode the beach areas and cut back bulkheads, groins, and jetties.[1] During heavy storms, waves break over the seawall and flood the lower streets.

In the March 1962 storm the boardwalk decking was lifted from its supports and deposited along with large amounts of sand from the beach against the structures facing the sea and in the streets. Beach front hotels and residences were badly damaged. Damage has also occurred in the hurricane storms of 1933, 1938, 1944, 1950, 1954, and 1955. Although no hurricane in recorded history has passed directly over the study area, Cape May is vulnerable to large ocean waves and tidal surges. Being at the southern tip of the

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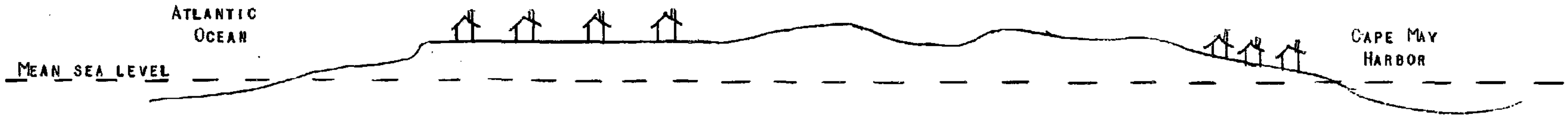
[1] U.S. Army Corps of Engineers: Shore of New Jersey-Barnegat Inlet to Cape May Canal, Beach Erosion Control Study, 86th Congress, 1st Session, House Doc. No. 208, 1959, pp. 42-47, and Horace G. Richards, A Book of Maps of Cape May, 1610-1878, Cape May Geographic Society, Cape May, N.J., 1954, pp. 24-28.

STUDY SITE NO. 10



	A	B	C	B	A
ZONE	BELOW MEAN HIGH TIDE	BETWEEN MEAN HIGH TIDE AND 10 FEET	BETWEEN 10- AND 20-FOOT CONTOUR	BETWEEN MEAN HIGH TIDE AND 10 FEET	BELOW MEAN HIGH TIDE
GEOMORPHIC TYPE	BEACH	FLAT TERRACE LAND WITH A FEW LOW MARSH AREAS - SANDS AND GRAVELS			TIDAL LAGOON MARSH
TYPE OF HAZARD	HEAVY WAVE POUNDING TO BEACH AND PROTECTIVE WORKS	AREAS BELOW THE 10-FOOT CONTOUR SUBJECT TO FLOODING	ONLY MINOR HAZARD, LITTLE FLOODING	AREAS SUBJECT TO FLOODING	TIDAL AREAS INUNDATED DURING STORMS
DEGREE OF HAZARD	SEVERE EROSION TO BEACH AND DAMAGE TO STRUCTURES	SEVERE HAZARD FROM FLOODING	MINOR	MINOR FLOODING	SOME MINOR FLOODING
STRUCTURES	NONE	MANY	SEVERAL	MANY	FEW
ADJUSTMENTS	BEACH BUILDING AND PROTECTIVE WALLS AND JETTIES	FEW	FEW	MINOR PROTECTIVE WORKS	MINOR PROTECTIVE WORKS TO MARINAS

FIGURE 2-10. DIAGRAMMATIC CROSS SECTION, CAPE MAY, NEW JERSEY

peninsula, Cape May is particularly exposed to large waves from the east, the south and the southwest. The waves converging on this area have cut away the continental shelf and are now eroding the mainland itself.

The Weather Bureau's Storm Surge Warning Map[1] indicates that most of the town of Cape May, except for a small central area over 10 feet, is subject to flooding in severe storms and evacuation is recommended for low lying areas and the settlements around Cape May Lighthouse. Cape May Lighthouse is west of the study site at the extreme southwest point of Cape May peninsula. Interviews with local residents placed the flood of record over 10 feet in some places near the beach.

Settlement history.[2] The earliest inhabitants of Cape May County were the Lenni-Lenapi Indians. Records show that this peninsula was visited by Henry Hudson as early as 1609. Subsequent settlement by the Dutch West India Company was succeeded by the English who were the first permanent white settlers in the area. The first known village, Town Bank was founded in the 1630's and was devoted to fishing and whaling.

Indeed, the 17th century may be thought of as the fishing and whaling period of the Cape May peninsula. By the early 1700's whaling declined and the area's fishing industry became supplemented by agricultural endeavors. In addition, pirates played a brief, but picturesque, role in early years of the 18th century.

The city of Cape May, or Cape Island as it is often known, existed in its early settled history as a tiny fishing village. In 1766, Robert Parsons ran an advertisement in a Philadelphia paper extolling the virtues of Cape May, New Jersey as a place to "resort for health and bathing in the water". It is upon this early pronouncement of Cape Island's attractions that Cape May bases its claim as the oldest seashore resort in the country. In any case, by 1801 a hotel had been built and by mid-century Cape May was famous for its large resort hotels.

A few recreational visitors or "resorters" appear to have visited the area in the 1760's, but visitors remained few in number until later years. The 1800's saw Cape May become one of the most famous and fashionable resorts in the country. At the same time fishing and farming prospered, but economically played only a secondary role to Peninsular Cape May's famous "watering-spots".

The early 1900's saw the recreation industry continue to prosper. However, World War I, a severe depression, and the mobility of the roaring twenties, wrought havoc with the resort hotel industry. It is only since World War II that this depressed condition has been reversed. The resort industry has again become the primary industry of the county.

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[1] U.S. Department of Commerce, Weather Bureau, Storm Surge Warning Map, No. 19, May 6, 1962.

[2] Based on field party notes assembled from various locally available sources.

In the Cape Island's earliest days, access was primarily by means of water transportation. On the water, packet ships soon gave way to a relatively efficient steam transport. As for land transporation stage coach lines were succeeded by the railroad in the 1860's and better roads and the early automobile in early 1890's. Recent roads and bridges have increased accessibility further.

Aside from the tourist industry, the only other important activity is fishing. A commercial Menhaden fishing fleet began in the 1850's and has continued to prosper in small degree. Today it is supplemented by the sportfishing engaged in by the more active of Cape May visitors.

Historically the Navy and Coast Guard have played important roles in the area. During World War I a large navy base was established on Cape Island. Base 9 was famous in both World Wars but in the late 1940's was handed over to the U. S. Coast Guard which now uses the base as a recruit training center.

Land use changes. The Cape May study site was completely developed at the time of the first available air photograph coverage in 1956. Changes in land use have therefore been small. The most important is an increase of 30 in the number of single family residences -- 24 of these are in the flood hazard zone. This increase has been in the form of increasing densities in already developed areas, so that no new acreage of residential land is recorded. (See table 2-10.)

There has also been a small increase in the number of commercial structures. The pattern of land use is shown in the overlay to figure 10 (appendix).

Adjustments to hazard. The major adjustment to hazard at Cape May is the large concrete seawall which keeps out all but the most severe storms. The wall was heavily damaged in the storm of March 1962 but has since been repaired.

Knowledge of the hazard is quite general in Cape May but there is little the average home owner or hotel manager can do. Private adjustments by seafront property owners include construction of small seawalls and bulkheads. Some filling has taken place in Cape May harbor for new marinas.

Future development. Cape May is a curious mixture of old and dignified Victorian structures, many of them large hotels, and the brash modern motels and marinas. In spite of the new developments the city retains a 19th century air and present plans for urban renewal call for a retention of as much of this atmosphere as possible. The city appeared likely to obtain the necessary Federal assistance for urban renewal at the time of our field survey.

Cape May is an example of a long established summer shore type of coastal development. Severe damage has been suffered in the past and is likely to occur again in the future. Adjustments to hazard are predominantly public and a reduction of damage could be achieved by a larger seawall which might destroy some of the amenities of the resort. Future growth and development hinge on plans for urban renewal, and flood damage potential is not likely to be substantially increased.

Table 2-10

Cape May, New Jersey

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures 1956	No. Structures 1963	No. Structures % change	No. Acres 1956	No. Acres 1963	No. Acres % change
A	5a Recreational	0	0	0	8	8	0
Tidal	Total	0	0	0	8	8	0
B	2 Commercial	103	110	+7	77	79	+3
	6a Residential	604	628	+4	177	177	0
	8 Undeveloped	0	0	0	273	270	-1
Tidal-10'	Total	728	763	+5	536	536	0
C	2 Commercial	35	36	+3	23	23	0
	6a Residential	132	138	+4	42	42	0
	8 Undeveloped	0	0	0	81	81	0
10'-20'	Total	179	186	+4	146	146	0
D	None in study area						
F	2 Commercial	100	103	+3	72	72	0
	6a Residential	552	576	+4	161	161	0
	8 Undeveloped	0	0	0	229	228	0
Flooded	Total	671	702	+5	479	479	0
All Zones	1 Industrial	3	3	0	2	2	0
	2 Commercial	138	146	+6	100	102	+2
	3 Public	7	8	+14	4	4	0
	4 Recreational	0	0	0	0	0	0
	5a Recreational	1	3	+200	11	11	0
	5b Recreational	2	2	0	0	1	na[2]
	6a Residential	736	766	+4	219	219	0
	6b Residential	20	21	+5	0	0	0
	8 Undeveloped	0	0	0	354	351	-1
	Total	907	949	+5	690	690	0

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] na -- Calculation not appropriate.

11. Wildwood Crest, New Jersey [1]

Wildwood Crest is a new, rapidly growing, summer shore area five miles northeast of Cape May. The study site occupies 3.3 miles of Atlantic coastline and extends south from Rio Grande Avenue in Wildwood City through Wildwood Crest to Cape May Inlet, and inland to Pacific Avenue (Ocean Drive) which runs down the center of the barrier island on which these communities are built. Total acreage is 995. (See figure 11 in the appendix.)

Physiography. Nearly half of this study site, about 45 percent, consists of a large sandy barrier island. (See cross section, figure 2-11.) This barrier island is the southernmost in New Jersey and, like the others to the north, is separated from the mainland by 4 to 5 miles of tidal marsh.

About 33 percent of this site consists of a wide 300- to 500-foot, gently sloping beach on the ocean isde of the sand barrier. This beach is non-cliffed and straight with very fine, almost clay-like, sand. This is one of the finest recreational beaches on the east coast mainly because of its width and gentle offshore gradient. Ten-foot high sand dunes have formed behind the beach at Two Mile Beach near the south end of the study site. Along the northern part of the beach scattered dunes occur between the new motels and housing developments. Most of the dunes here have been leveled by man and fill has been added to raise the structures above the flood mark. The remaining 22 percent of the area is marshland and tidal lagoons.

Storm hazard. The wide beach at Wildwood Crest helps to protect the area from storms which are relatively low in frequency. There is no seawall however and the summer homes and motels that line the coast are largely unprotected by engineering structures. The shallow offshore continental shelf plus the wide beach combine to absorb most of the wave energy before it reaches the dunes and coastal property. Hurricanes usually offer the greatest threat to this community. During the March 1962 storm which caused heavy damage on other parts of the New Jersey coast, the Wildwood Crest area received less wave damage than most other places. The town was affected however, the beach was eroded and several feet of water covered the streets.

Field work established a flood of record of 8 to 9 feet above mean sea level for the Wildwood Crest study site. With only a few dune areas and a small section along Atlantic Avenue over 10 feet in elevation, flood inundation remains a hazard for the future.

Settlement history.[2] Prior to the 1880's there was little development in the Wildwood area. Mr. Phillip P. Baker called the area uninhabitable and inaccessible in 1881, but proceeded to turn Indian trails into a railroad line, and a small fishing village into a summer resort.

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[1] Field work by Robert Arnold and Richard Hecock. We are indebted to the following persons who supplied information: Mr. Donald Little, Mr. Edwin Nesbitt, and Mr. James Byington.

[2] Based on field party notes assembled from various locally available sources.

STUDY SITE NO. 11

ZONE	BETWEEN MEAN HIGH TIDE AND THE 10-FOOT CONTOUR	MEAN HIGH TIDE TO ABOVE 10-FOOT CONTOUR	BELOW MEAN HIGH TIDE
GEOMORPHIC TYPE	LARGE SANDY BARRIER ISLAND	LOW 10-FOOT HIGH SAND DUNES	WIDE SANDY BEACH AND CONTINENTAL SHELF. GENTLE GRADIENT
TYPE OF HAZARD	LOW AREAS SUBJECT TO FLOODING	UNDERCUTTING OF DUNES BY WAVES	MINOR EROSION TO BEACH
DEGREE OF HAZARD	MINOR	SOME HAZARD FROM EROSION	MINOR TO SEVERE EROSION DEPENDING UPON STRENGTH OF STORM AND TIDES
STRUCTURES	MANY SUMMER HOMES AND MOTELS		FEW
ADJUSTMENTS	FEW	MOST FRONT DUNES HAVE BEEN REMOVED. BULK-HEADS BEING CONSTRUCTED	JETTIES AND GROINS HAVE BEEN BUILT TO HELP BUILD BEACH

FIGURE 2-11. DIAGRAMMATIC CROSS SECTION, WILDWOOD CREST, NEW JERSEY

After obtaining a small tract of land called Holly Beach, he laid out lots and streets. Next he negotiated for and brought to Wildwood a branch of the railroad in 1895. Shortly, highways began to bring automobiles and Wildwood enjoyed rapid expansion as a residential resort.

In 1907 streets were laid out for an additional development known as Wildwood Crest. In 1910 the Borough of Wildwood Crest was incorporated. Development in this area expanded rapidly, particularly in the areas bordering Wildwood itself. This development resembled the residential type of development in Wildwood. After hard times in the 1930's and early 1940's, Wildwood Crest had a very rapid expansion, and commercialization of its resort facilities in recent years.

Land use changes. Wildwood Crest is a rapidly growing summer shore community. There has been a substantial increase in the number of single family residences, mostly summer homes, since 1956. Most of these are above the flood hazard area.

An even more spectacular growth has occurred in the commercial strip in the row of blocks closest to the ocean. This consists primarily of shops, restaurants, motels and other services. A large proportion of this new commercial development is in the flood hazard zone. It seems unfortunate that this more valuable property with higher damage potential should be located in such a vulnerable position. The focus of the community, however, is the beach. This is where the customers are or want to be. Hence those functions which can afford to pay the highest rents buy themselves into the best business locations. It so happens in Wildwood Crest that the best business sites are also largely in the area exposed to flood hazard. The pattern of land use is shown in the overlay to figure 11 (appendix). Recorded land use changes are shown in table 2-11.

Adjustments to hazard. With very few exceptions the residents and entrepreneurs of Wildwood Crest felt that storm hazard was slight and not a cause for major concern. This feeling of confidence seems to stem largely from the experience of the March, 1962 storm when little damage resulted in spite of the severity of the storm and the heavy damage elsewhere along the New Jersey coast. Accordingly there are few adjustments to hazard by private citizens. In no case did a respondent express a desire to move or to be in a less hazardous location. Some residents located two blocks from the ocean front expressed relief that they were not so exposed.

The feelings of public officials were not as confident and optimistic as those of private citizens. The city engineer expressed some concern about the development and did not want to see buildings move any closer to the beach. However, the borough has decided, since the storm of March 1962, to sell some beach front lots for the development of motels. To protect these motels an ordinance was under consideration to require property owners to provide bulkheads at their own expense.

Future developments. In 1963 there were approximately 100 acres of land left undeveloped. Local officials were of the opinion that this land and other land outside the study area would be fully developed within five years. The undeveloped land is being devoted to the construction of single and double family residences with the exception of the land east of Atlantic Avenue which is zoned for motels.

Table 2-11

Wildwood Crest, New Jersey

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures 1956	No. Structures 1963	No. Structures % change	No. Acres 1956	No. Acres 1963	No. Acres % change
A	3 Public	0	0	0	285	285	0
	4 Recreational	0	0	0	120	120	0
Tidal	Total	0	0	0	405	405	0
B	2 Commercial	284	364	+28	47	77	+64
	3 Public	8	9	+12	205	205	0
	6a Residential	510	609	+19	138	145	+5
	8 Undeveloped	0	0	0	141	102	-28
Tidal-10'	Total	805	985	+22	564	564	0
C	2 Commercial	16	16	0	2	5	+150
	6a Residential	49	55	+12	15	15	0
	8 Undeveloped	0	0	0	6	3	-50
10'-20'	Total	66	72	+9	26	26	0
D	None in study area						
F	2 Commercial	56	118	+111	9	41	+356
	3 Public	5	9	+80	450	450	0
	4 Recreational	1	1	0	151	151	0
	6a Residential	59	62	+5	5	5	0
	8 Undeveloped	0	0	0	60	27	-55
Flooded	Total	122	191	+57	677	677	0
All Zones	2 Commercial	300	380	+27	49	82	+67
	3 Public	9	10	+11	493	493	0
	4 Recreational	1	1	0	151	151	0
	5a Recreational	1	1	0	2	4	+100
	6a Residential	559	664	+19	153	160	+5
	6b Residential	1	1	0	-	-	
	8 Undeveloped	0	0	0	147	105	-29
	Total	871	1057	+21	995	995	0

[1] Minor land uses omitted and total may exceed land uses enumerated.

Wildwood Crest is an example of a rapidly expanding summer shore type of development. The area has escaped heavy damage in the past and the storm hazard is viewed optimistically. There is a widespread lack of adjustments to hazard and protective dunes have been removed. New flood damage potential, especially of commercial property, is increasing rapidly and the area could suffer very severe damage from a future storm.

12. Dennis, Massachusetts[1]

The sixth example of summer shore development is at Dennis, Massachusetts. The study site includes four miles of coastline on the south shore of Cape Cod. It extends from South Sea Avenue in West Yarmouth, east to the South Pond River in West Dennis. The inland limit of the study site is about one mile from the coastline. Political divisions include a small section of South Yarmouth, and parts of West Yarmouth, and West Dennis. The total area is 2,178 acres. (See figure 12 in the appendix.)

Physiography. Uplands constitute 74 percent of area, marshland 19 percent, and beaches 7 percent. Characteristics of glacial topography are interwoven with those features which are typical of a low, drowned, coastal region. The study area is quite flat with numerous small tidal channels, inlets, lakes, and marshes. These fill the low areas between the beach and higher ground.

The so-called "uplands" of this study site are a very gently sloping outwash plain which covers an earlier glacial terminal moraine. No bedrock is exposed at the surface but stratified coarse materials, in uneven distribution, present an irregular, undulating, surface unsuited for agriculture. Most of the upland is between 10 and 20 feet above mean sea level. Only a few areas of the study site are over 20 feet. To the north of this site there is higher ground which represents a moraine left by the glacier as it retreated. This moraine makes up the backbone of Cape Cod. The materials carried off the moraine by glacial meltwaters flowed south and formed the outwash plain of the study site.

The second major physiographic type is marshland that has formed in the low areas under five feet. Marsh grass covers the silts and clays deposited by the short rivers flowing through the area. The largest of these rivers is the Bass River which divides the study site. Figure 2-12 shows the amount of marsh filling that has taken place between 1886 and 1961. In the early days of settlement even more of the study site must have been marsh or bog topography.

Beaches, averaging from 100 to 300 feet wide with a gentle offshore gradient, are the third physiographic type. The entire coast is non-cliffed, but has small, regular, straight stretches of beach that have been separated by jetties near the river mouths and groins where beach protection is needed. The two main bathing beaches are Davis Beach and Sea Gull Beach. Very few sand dunes remain behind the beaches because these original small coastal features have been leveled.

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[1] Field work by Robert Gardula and Roger Kasperson. We are indebted to the following person who supplied information: Mr. Donald A. Crane.

The site is made up mainly of wave deposited or wind blown sand underlain by glacial tills and outwash. (See cross section, figure 2-13.) Large areas of lowland have been filled in. The non-filled sections are either sand or silt and clay depending upon whether the locality is a beach or tidal marsh.

Vegetation on the upland surfaces is predominantly mixed trees with scattered groves of pines, and herbaceous plants. On the tidal flats marsh grass is found, but on the beaches, vegetation is largely absent.

Storm hazard. Although storm frequency is relatively high, this study site does not have as high a degree of hazard as might be expected from its very low elevation above mean sea level and its southward facing coast. A very shallow shelf extends about one-half mile into the ocean. This shelf is an extension of the glacial outwash plain and although it is narrow it is wide enough to prevent the buildup of large waves. The swells during severe storms drag bottom, crest up, and break before reaching the beaches. Many of the waves therefore become spilling and surging breakers rather than large plunging breakers which do great erosive work to the beach and coastal structures. Spilling breakers lose much of their energy as they cross this half-mile stretch of shelf.

Damage at this site was found to be localized with flooding of low areas, cellars, and structures being the greatest danger. There is some undermining of structures by waves along the immediate beach.

Major areas subject to flooding include the ocean edge of the beach; the tidal marshes and banks of the river beds; and the banks of the larger ponds where water is able to cross the lowlands and raise their level. The marsh and pond areas found north of Route 28 and north of the Dennis study site are also considered probable damage areas on Crane's maps of coastal flooding.[1] The Weather Bureau's Storm Surge Warning Map[2] lists major flooding and evacuation problems south of Route 28, stating that beaches are subject to heavy wave action.

The hazard zone diagram (figure 12, appendix), drawn after interviewing local residents of the area, puts the maximum flood line at about 8 to 9 feet above mean sea level. From extreme low water to extreme high water there is a range from 5 to 17 feet elevation. Minor flooding begins to take place at 4 feet above mean sea level. The cellars of summer houses are flooded at 6.4 feet, and whole areas go under water at 7.7 feet. The new housing development in the middle of the study site bordering on the Bass River and Ware Creek is barely 10 feet above mean sea level. It was found that any sections of the site under 10 feet were subject to inundation. Over 194,000 dollars worth of flood damage occurred to the town of Dennis during the 1954 hurricane.[3]

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[1] Donald A. Crane, Coastal Flooding in Barnstable County, Cape Cod, Mass., Mass. Water Resources Comm., December, 1962, p. 21.

[2] U.S. Department of Commerce, Weather Bureau, Storm Surge Warning Maps, August. 1962.

[3] Donald A. Crane, op. cit., Table VII, p. 27.

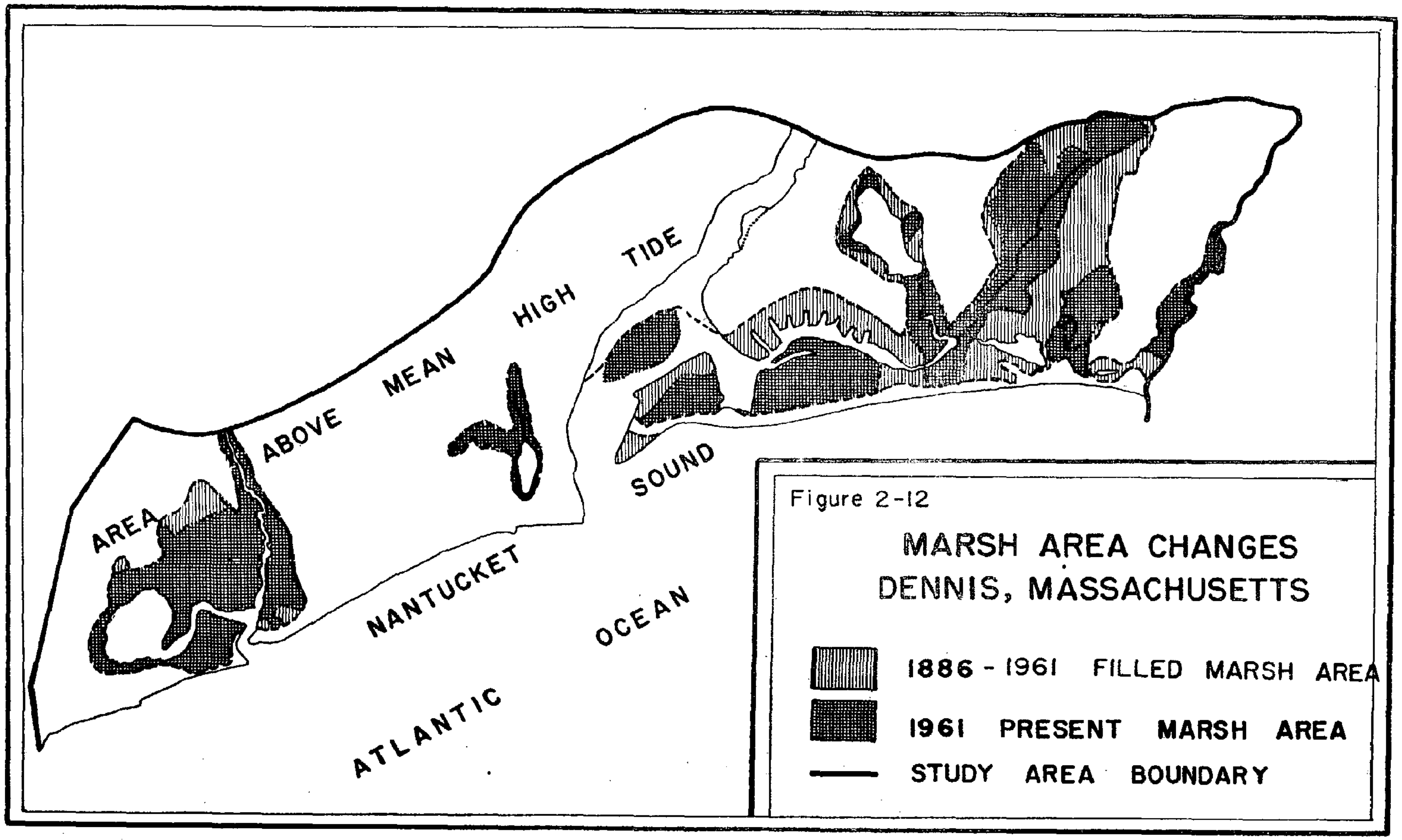

Figure 2-12

MARSH AREA CHANGES
DENNIS, MASSACHUSETTS

STUDY SITE NO. 12

	C, D	A	B	A
ZONE	ABOVE 10 FEET, BUT BELOW 30 FEET	BELOW MEAN HIGH TIDE	ABOVE MEAN HIGH TIDE BUT BELOW 10 FEET	BELOW MEAN HIGH TIDE
GEOMORPHIC TYPE	ROLLING UPLAND COVERED WITH GLACIAL TILL. SCATTERED ROUNDED FRESH WATER PONDS. GRAVELS AND CLAYS	TIDAL CHANNELS AND LOW MARSHLAND. SILTS AND CLAYS	SANDY BARRIER SPIT	WIDE SANDY BEACH AND GENTLE OFF-SHORE GRADIENT
TYPE OF HAZARD	MINOR FLOODING IN THE LOW AREAS	TIDAL INUNDATION DURING SEVERE STORMS	FLOODING AND DUNE EROSION	FLOODING AND BEACH EROSION
DEGREE OF HAZARD	MINOR	MODERATE TO SEVERE	SEVERE IN LARGE STORMS	SEVERE IN LARGE STORMS
STRUCTURES	MANY	FEW	FEW	FEW
ADJUSTMENTS	FILLING IN OF LOW MARSH AREAS FOR HOUSING DEVELOPMENTS	CHANNELS ARE DREDGED AND IN PLACES PROTECTED	REMOVAL OF DUNES. A FEW SEA WALLS	JETTIES AND GROINS TO PROTECT BEACH

FIGURE 2-13. DIAGRAMMATIC CROSS SECTION, DENNIS, MASSACHUSETTS

This study site receives the most severe damage from hurricanes moving northeastwards. The 1938, 1944, and 1954 storms were the most severe.[1] Other storms include the cyclonic depressions which develop rapidly as a coastal secondary in the region of Cape Hatteras with the main depression over the continent. Wave development can take place very fast as the storm center moves northeastward and passes over the ocean. However these storms are usually of short duration.

Settlement history.[2] The early settlement of South Yarmouth and West Dennis was contemporaneous with that of the nearby towns of Sandwich and Barnstable in the late 1630's and early 1640's. The division of these settlements into individual villages was occasioned by the establishment of distinct parishes within the church. Dennis, for example, was organized as a new town in 1793.

Within the study area, the chief occupations of the inhabitants centered upon the Bass River and the fishing industry that grew upon within this sheltered waterway. By 1795, 3 wharves had been built on the east side of the Bass River, and soon after 1800, 247 men were employed in the fishing industry in West Dennis and nearly 1100 tons of mackerel and codfish were taken.

Despite the economic focus of the area upon the Bass River, settlement tended to grow up along major road arteries rather than in the land adjacent to the river. Main Street in both South Yarmouth and West Dennis was the most heavily populated route and much of this was located above the 20-foot contour.

The focus of both West Dennis and South Yarmouth encouraged intercourse between the two communities. Even though the Bass River was not crossed by a bridge until 1870 in this area, a ferry was present to facilitate travel. Throughout the history of the study area, South Yarmouth has provided the central place functions for the local population. Much of the business of West Dennis was conducted here.

In the early 1800's, population growth in the area was rapid. By 1802 there were 100 dwellings south of County Road in West Dennis. They had been erected so rapidly that essentially all of them were only one story high. In the first half of the 19th century, the study area broadened its economic base by supplementing its fishing industry with other economic activities. The salt industry developed rapidly (as in Wellfleet) so that by 1803 there were 24 salt works in West Dennis alone. Ship building became important and while large-class vessels were built on the Bay side, considerable construction of vessels in the eight-ton class took place along the Bass River. In South Yarmouth, a boot and shoe company was established in 1829. Within the study area, the rapid growth of maritime and associated industries produced a rapid population growth near the Bass River and in South Yarmouth particularly. This led to the development of a well-defined village nucleus prior to the Civil War.

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[1] Donald A. Crane, op. cit., pp. 9-15.

[2] Based on field party notes assembled from various locally available sources.

After the Civil War, fishing declined as did the population of the area. In the early 1900's, the decline was checked by the beginnings of tourism and seasonal residence in the area. As would be expected much of this population increase occurred in areas along the coast. In South Yarmouth, rapid population growth took place south of South Shore Avenue and along the Bass River, while in West Dennis major increases took place along the Bass River and south of Lower County Road. In both cases, the conversion of the economy of the area from fishing to resort activities substantially increased the population below the 10-foot contour and thereby augmented the damage potential from storms.

Land use changes. There has been rapid growth in the area. In 1952 the population still showed a marked concentration along and close to the major roads, and in the old village centers. By 1963 settlement had spread widely to include nearly all of the large but previously undeveloped tracts above marshland level. Marsh areas have also been filled in and used as development sites as in the case of Surfside Village.

The main expansion has been in the construction of single family residences, many of them as summer homes for seasonal residents. Of the 2227 new single family residences built in the period 1952 to 1963, 637 or one-quarter of them have been built in a flood hazard area. Development has been concentrated on and near to the coast both on high and on filled-in marshland.

The area has also been developed commercially. Prior to 1952 tourist accomodation was restricted almost entirely to guest homes, cottages, and cabins. The growth of large shore-front motels since 1952 has been extremely rapid. Another area of motel development is along Route 28.

Expansion into marshland areas has met with some local opposition. Local residents argue that marshland reclamation will adversely affect the shellfish and fish industry; that it will change for the worse the pattern of coastal flooding; and that it is undesirable because the marshlands have aesthetic appeal and recreational value which new subdivisions do not have. Many think that the area is becoming too commercialized and that all further development should be stopped.

The pattern of land use is shown in the overlay to figure 12 (appendix). Recorded land use changes are shown in table 2-12. The process of land fill has gone on for a long time and extensive changes have been made as shown in figure 2-12.

Adjustments to hazard. For the most part, interviews in the study area suggest that while most of the inhabitants interviewed expected a serious storm or hurricane in the future, they do not expect serious damage. Among those who do expect damage, it does not appear to affect seriously the decision to locate there because this segment of the population is in a high-income class and are often willing to run the risk of damage. In fact, several expressed the opinion that in a future storm they would suffer damage, but were still unwilling to locate elsewhere.

The inhabitants who have recently located in a high hazard zone are very often unaware of storm hazard. The people showing most awareness are the long-time residents

Table 2-12

Dennis, Massachusetts

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures			No. Acres		
		1952	1963	% change	1952	1963	% change
A	4 Recreational	0	0	0	53	53	0
	5b Recreational	0	0	0	54	43	-20
	8 Undeveloped	0	0	0	431	431	0
Tidal	Total	0	0	0	539	539	0
B	2 Commercial	25	214	+756	7	90	+1186
	4 Recreational	2	2	0	66	66	0
	5b Recreational	0	0	0	54	42	-22
	6a Residential	497	1319	+165	215	307	+43
	8 Undeveloped	0	0	0	298	123	-59
Tidal-10'	Total	524	1535	+193	641	641	0
C	2 Commercial	34	123	+262	16	54	+238
	6a Residential	716	2092	+192	429	664	+55
	8 Undeveloped	0	0	0	454	181	-40
10'-20'	Total	750	2219	+196	900	900	0
D	2 Commercial	4	36	+800	7	16	+129
	6a Residential	119	148	+24	28	38	+36
	8 Undeveloped	0	0	0	51	26	-49
> 20'	Total	125	188	+50	98	98	0
F	2 Commercial	23	192	+735	6	83	+1283
	4 Recreational	2	2	0	119	119	0
	5b Recreational	0	0	0	109	85	-22
	6a Residential	484	1121	+132	204	290	+42
	8 Undeveloped	0	0	0	608	445	-27
Flooded	Total	509	1315	+158	1047	1047	0
All Zones	2 Commercial	63	373	+492	30	160	+433
	3 Public	22	8	-64	13	19	+46
	4 Recreational	2	2	0	119	119	0
	5a Recreational	0	0	0	2	25	+1150
	5b Recreational	0	0	0	108	85	-21
	6a Residential	1332	3559	+167	672	1009	+50
	8 Undeveloped	0	0	0	1234	761	-38
	Total	1399	3942	+182	2178	2178	0

[1] Minor land uses omitted and total may exceed land uses enumerated.

who themselves have experienced serious damage from past storms. Several inhabitants who were located above the 10-foot contour cited elevation above sea level and distance from the beach as an important factor in location.

Commercial establishments interviewed showed an awareness of storm occurrence in the future, but also did not anticipate serious future damage. It should be noted that most of these interviews were with very recent establishments. Most seemed to feel income from location (usually on beach for motels) justified whatever damage occur.

There is a very low rate of adoption of adjustments to hazard. There is no public protection, but some private citizens have adopted their own adjustments. These include use of seawalls and steel bulkheads especially for commercial property. Some houses have been erected on piles or cement block foundations. One house has its furnace on the second floor.

In contrast some new subdivisions are being built at the head of the beach on land formerly occupied by dunes. Commonly the dune is used as fill for the marshland behind the dune, and the whole site is leveled, thus increasing the danger of flooding. As noted above a controversy surrounds marshland reclamation. Zoning, building, and subdivision regulations are in force in Yarmouth, where five feet of fill are required for subdivisions adjacent to tidewater, and all low lying land must be raised to 7.3 feet above mean sea level before building.

Future development. Undoubtedly one important factor in the rapid development in the last 10 years has been the important change in accessibility. In the mid-1950's, the mid-Cape highway (route 6) was constructed. This greatly shortened the time requirement and lightened traffic density of trips to the Cape.

This improved accessibility, plus the recreational attractions of the area, especially its excellent beach and relatively warm water, are likely to continue to bring development to Dennis until all available land is developed. There are forces opposing further development, but these are unlikely to be able to achieve more than a stricter enforcement of building codes and subdivision regulations, and perhaps some reduction in the pace of development. It is also likely that the re-zoning of coastal areas from residential to commercial use will become more difficult with time.

In addition to beach users, the Bass River, with its new marinas offers boating and fishing as a recreational pursuit and considerable potential exists for an increase in this activity.

Dennis is an example of rapidly expanding coastal development, where substantial increases in flood damage potential are in process of creation. This development continues in spite of some local opposition and is surrounded by a good deal of uncertainty as to the likely effects of future flooding. In particular there is need for the establishment of minimum levels of fill for building purposes, especially in West Dennis, but there is a lack of precise information about the degree of hazard which could be used to support the adoption of the necessary building codes.

13. Nags Head, North Carolina[1]

Nags Head is a summer resort community on Bodie Island, one of the outer banks of North Carolina. It is 14 miles north of Oregon Inlet and is reached by causeway from the mainland via Roanoke Island. The study area includes 9.3 miles of coast line, extending from the north end of Jackey Ridge just south of the Wilbur Wright Memorial, south to the northern part of Cape Hatteras National Seashore. The total area is 3,505 acres, and the extent inland varies from 1 to 1.5 miles. (See figure 13 in the appendix.)

Physiography. The entire study site is part of a narrow sand barrier spit 65 miles in length. Although the name Bodie Island applies to the whole spit, it is divided by several inlets into a number of barrier islands.[2] The study site has four landform sub types: beach and coastal sand dunes; sand flats; dune masses; and tidal marshes. Bordering on the Atlantic Ocean is a 150- to 399-foot wide, nearly straight, sandy beach. It is backed by a series of low scattered dunes which in places reach a height of 24 feet. These two units make up about 10 percent of the study area. Dune grasses, particularly American beach grass (Ammophila breviligulata), and sea oats (Uniola paniculata) grow well on the low dunes when undisturbed, but they are not able to survive the heavy pounding of storm waves. Thus, the coastal dunes are not very effective in stopping storm inundation.

In the northern part of the study area, a narrow sand flat lies behind the ocean beach and coastal dunes. It appears to be the main source area for the large dune masses which make up the backbone of Bodie Island. These low sand flats constitute about 44 percent of the Nags Head study site. The largest dune complex, called Jackey Ridge, contains large rounded dunes reaching a height of 138 feet. Although only five miles long and averaging half a mile in width, this dune mass is able to withstand storm-driven wind and waves. Winds from several directions keep the dunes in rounded heaps, but some of the sand migrates west into Roanoke Sound. All the sand masses combined total about 22 percent of the area under study.

The fourth landform subdivision is the low marsh areas behind the barrier dunes, constituting about 24 percent of the study site. The largest marsh area is in the southern part of the site. According to the Park Engineer for the Cape Hatteras National Seashore, there has been natural filling by sand which has been blown and washed in from the coastal dunes and beach. Aerial photographs taken in 1962, soon after the March storm, show large sand fingers extending into the marsh areas from the blowouts. The natural filling is aided by man, who has dug canals to drain the area for mosquito control and to prepare the area for possible housing developments.

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[1] Field work by Robert Arnold and Richard Hecock. We are indebted to the following persons who supplied information: John Donnelly, Mr. Edward Nash, Mr. William Foreman, Mr. Rundell, Mr. Williams, and Mr. Cahoon.

[2] Corps of Engineers, North Carolina Shore Line, Beach Erosion Study, 80th Cong., 2nd Sess., Doc. No. 763, 1948, pp. 6-8; and Beach Erosion at Kitty Hawk, Nags Head, and Oregon Inlet, N.C., 74th Cong., 1st Sess., House Doc. No. 155, 1935, pp. 4-5.

Sand is the predominant material making up the barrier spit. A thin veneer of clay and silt occurs in the tidal marsh areas. Less than a hundred years ago the Outer Banks had a thick covering of vegetation which extended from the sound almost to the edge of the ocean. Today, little vegetation exists on the coastal dunes, none of the large shifting sand dunes, and only small protected areas have pines which grow from 40 to 60 feet high. In the marshes, low, salt tolerant herbs and grasses are found. (See cross section, figure 2-14.)

Storm hazard. Both hurricanes and northeasters have caused considerable damage to the Nags Head area, but the March 1962 storm was one of the most severe that has ever struck the area. In a post-flood report prepared by the Corps of Engineers,[1] an estimated tide of from 7 to 9 feet above mean sea level occurred, and this was capped by 12-foot breakers.

From interviews and other field information, a conservative estimate would place flood-free land only above the 15-foot contour. Evidence indicates that all the land area immediately behind the ocean beach is subject to flooding because of dune washouts.

Not only is there a high degree of hazard from the ocean at Nags Head, but also, because of the size of Pamlico Sound, the western side of the barrier bar is subject to severe flooding and wave damage.

With the exception of a few areas where 60- to 130-foot dune masses occur, as along Jackey Ridge, no section is safe from flooding produced by high storm tides and strong winds. Damage that has occurred at this site includes flooding, beach erosion, frontal structural damage, wind damage, and sand deposits around buildings and across roads.

The storm of 6-8 March 1962 (Ash Wednesday storm as it is called at Nags Head) was much more destructive than most of the hurricanes crossing this study site. A deep low-pressure area centered 300 miles south of Cape Hatteras on the morning of March 5, moved very slowly north during the next three days bringing 30- to 40-foot high waves against the coast. Although maximum wind velocities at Hatteras reached only 60 miles per hour storm surges were 8 to 9 feet above mean tide with breakers up to 12 feet high. Over a million and a half dollars worth of damage resulted from this one storm. Damage to structures was particularly heavy with three fishing piers being destroyed. The shore was badly eroded resulting in very steep beach profiles.[2]

Coastal changes. In the southern part of the study area, a few miles from Oregon Inlet, natural filling by sand migrating over or through gaps in the coastal dunes is filling in the tidal marshes. Park naturalists report that these low areas no longer flood regularly.

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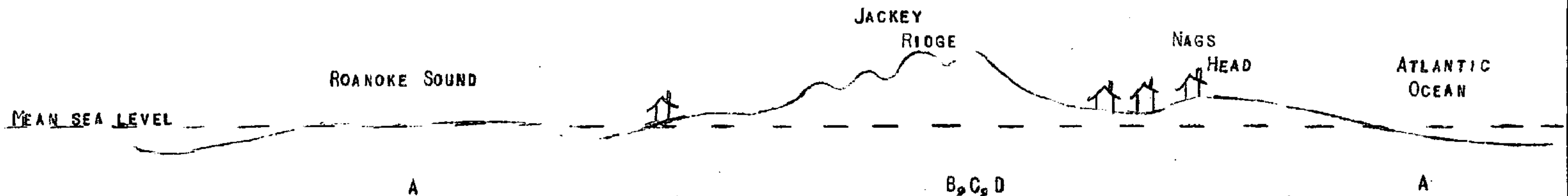
[1] Corps of Engineers, North Carolina Coastal Areas: Storm of 6-8 March 1962 (Ash Wednesday Storm): Final Post-Flood Report, U.S. Army Engineer District, Wilmington, North Carolina (6 September, 1962), pp. 1-11 and attachment 1.

[2] Corps of Engineers, North Carolina Coastal Areas, op. cit., pp. 1-11.

STUDY SITE NO. 13



Zone	Below mean high tide	Above mean tide to above the 20-foot contour	Below mean high tide
Geomorphic Type	Low tidal marsh silts and clays	Barrier island with sand flats and large shifting sand dunes in places over 100 feet high	Wide sandy beach and continental shelf with gentle gradient
Type of Hazard	Flooding and wave damage	Migration of dunes and some water inundation	Flooding, wave damage, and erosion
Degree of Hazard	Severe	Minor hazard from wind blown sand and minor flooding in low areas	Severe erosion to beach, dunes and structures
Structures	Few	Numerous summer homes along the Atlantic coast. A few structures along Pamlico Sound	Few
Adjustments	Few	Many individual adjustments to protect dunes and structures	Protection of the beach with the movement of sand

Figure 2-14. Diagrammatic cross section, Nags Head, North Carolina

A major change is the gradual retreat of the coast which for the Nags Head region appears to be from 3 to 5 feet per year over the last 25 years. However, where the beach erodes in one area, it may build up in another. The shore processes are dynamic. Change is constant, and off-shore undulations can shift overnight. There is tear-down and build-up of beach sand, but the over-all governing factors are such that the net long term result is loss of land mass. Thus, the Outer Banks are now in most places being eroded and moved toward the mainland by a combination of long shore currents, wave and tide action, and by wind movement which generally carries the sand inland.[1]

Settlement history. Although most of the buildings in Nags Head are on the ocean side, this has not always been the case. In the early days cottages were built on the Sound side beginning in the 1830's. A hotel was built in the early 1840's and there was a bowling alley by 1850. Horseback riding and hunting were popular among the Middle Atlantic plantation owners who frequented this popular resort.

Throughout most of the European colonization of North America, the North Carolina Outer Banks have been sparsely populated.[2] The native "Bankers" who engaged in fishing and farming were few. Some of them were reputed to have been involved in more colorful activities such as smuggling, blockade running, piracy, and wrecking.[3] Nags Head was an exception to this pattern of a remote, simple, and unlawful life. It is one of the oldest vacation resorts on the east coast.

By the time of the Civil War, Nags Head could claim a long history as a seaside resort. It was also unusual in another way. It had a large number of private cottages at a time when hotels were dominant.

The area had a reputation as a healthy place, largely because of the absence of malaria.[4] In addition, the beaches and the surf enjoyed increasing popularity among

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[1] Edward Nash, Beach and Sand Dune Erosion Control at Cape Hatteras National Seashore, A Five Year Review (1956-1961), U.S. Dept. of the Interior, National Park Service (Manteo, North Carolina: Cape Hatteras National Seashore, 1962), p. 12.

[2] The history of the Outer Banks is described in Gary S. Dunbar, Historical Geography of the North Carolina Outer Banks, Coastal Studies Series, // 3, James P. Morgan, ed. (Baton Rouge: Louisiana State University Press, 1958), 234 pp.; and David Stick, The Outer Banks of North Carolina, 1584-1958 (Chapel Hill: University of North Carolina Press, 1958), 352 pp.

[3] Nags Head reportedly gets its name from a legend which tells of Bankers who attached lights to horses' heads. As the animals were driven along the beach, confused ships at sea were lured to their doom in the treacherous surf of the Outer Banks. From this activity came the name Nag's Head. The apostrophe has since been dropped.

[4] The summer residents, of course, could not account adequately for the healthfulness of the area. The characteristics and causes of malaria were not discovered until later. The southern planters only knew that they were less likely to get sick here at Nags Head than they were in the heat and humidity of their homes.

19th century American visitors. Nags Head was easily reached by steamship or schooner from Norfolk or Elizabeth City. An early record claims that "of 500 or 600 visitors, a greater or less number of them are on the beach or bathing at all hours of the day."[1]

After a brief decline during the Civil War, Nags Head recovered its former prominence as a resort. Another hotel was constructed and summer residents began building cottages on the ocean side of the island. A long time resident of the area[2] claims that most of the large summer cottages in the northern part of the study area were built in the first two decades of the 20th century. The Cape Hatteras National Seashore, administered by the National Park Service, was established on January 12, 1953. This park includes sections of the Outer Banks from Nags Head to Ocracoke Island.

The first available photographs of the study site are for 1945. At that time there were probably less than 50 structures in all, and one fishing pier. It is not possible to state precisely the number of structures because only part of the area is covered by the 1945 photographs. These structures were old then, many of them dating back to the 1900-1920 period. In spite of the long history of recreational use, especially summer cottages, it was not until after 1945 that rapid development took place.

By the time a new topographic survey was made by the United States Geological Survey in 1953, the total number of structures had risen to 449. All of these were located in the flood zone established arbitrarily at 15-foot elevation, and most of them were below 10 feet above mean sea level. Structure counts by use and hazard zone are listed in table 2-13. Over half the increase between 1945 and 1953 was in single-family residential buildings, mostly summer cottages. A somewhat smaller number of new commercial buildings were also opened during this period. Most of this new development occurred north of Whalebone Junction, along the beach road. The normal process of development was for buildings to be erected on the ocean side first, between the road and the seashore, and then on the Sound side later.

The period since 1953 has been one of continued expansion and development. There has been a change in both location and type of development, however. Since 1953 more development has occurred south of Whalebone Junction, and a rather larger proportion has been in the construction of motels and restaurants. Two new fishing piers have also been opened.

The Sound side remains largely undeveloped, in spite of the fact that it was here that the development of Nags Head first started. There are two Sound side roads with cottages along them now, and a new State highway now parallels the beach road, also on the Sound side. It seems likely that this road will be the focus of new development in future years as the ocean side becomes filled. The pattern of land use is shown in the overlay to figure 13 (appendix)

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[1] Report of the Superintendent of the Coast Survey, 1849, p. 87 quoted in Gary S. Dunbar, op. cit., p. 38.

[2] Mr. Jones, a Manteo Insurance Agent.

Table 2-13

Nags Head, North Carolina

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures			No. Acres		
		1953	1963	% change	1953	1963	% change
A	8 Undeveloped	0	0	0	772	772	0
Tidal	Total	0	0	0	773	773	0
B	2 Commercial	132	215	+63	56	79	+41
	6a Residential	140	221	+57	99	129	+30
	8 Undeveloped	0	0	0	1646	1593	-3
Tidal-10'	Total	284	457	+61	1820	1820	0
C	2 Commercial	69	179	+159	34	46	+35
	6a Residential	93	233	+150	80	92	+15
	8 Undeveloped	0	0	0	586	562	-4
10'-20'	Total	165	414	+151	701	701	0
D	8 Undeveloped	0	0	0	209	209	0
> 20'	Total	0	0	0	211	211	0
F	2 Commercial	201	394	+96	91	126	+38
	6a Residential	233	454	+95	181	223	+23
	8 Undeveloped	0	0	0	2718	2641	-3
Flooded	Total	449	871	+94	3010	3010	0
All Zones	2 Commercial	201	394	+96	91	126	+38
	3 Public	9	6	-33	20	20	0
	5a Recreational	6	8	+33	0	0	0
	6a Residential	233	454	+95	181	223	+23
	6b Residential	0	9	na[2]	0	0	0
	8 Undeveloped	0	0	0	3213	3136	-2
	Total	449	871	+94	3505	3505	0

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] na -- Calculation not appropriate.

Adjustments to hazard. There is a high degree of awareness of the storm hazard at Nags Head and this is accompanied by a wide range of adjustments and a high rate of adoption of adjustments by private citizens. Adjustments include the elevation of many houses on piles; the use of rock rubble to form a seawall; the use of snow fences to build dunes; increasing the height of dunes with a bulldozer and stabilizing the dunes by planting. Timber from structures are commonly strengthened by liberal use of cross ties. One resident also reported lobbying activity in Washington in support of an insurance bill for flood damage.

In spite of the high degree of awareness of hazard and high degree of experience and familiarity with damage (almost every resident could state precisely the dates of the Ash Wednesday storm - March 6-8, 1962), there is little or no effect on locational decisions. A general attitude appears to be that the amenities of the site justify the risk provided that common sense adjustments are made.

Public adjustments are prominent at the Cape Hatteras National Seashore where a program of bulldozing sand into dunes, use of storm fences and seeding the dunes, has resulted in the creation of a stable, 10-foot barrier sand ridge along most of the sea front of the area. Proposals have also been made for the provision of more protection by the construction of groins, jetties, and seawalls, but action on these proposals did not appear imminent in the summer of 1963.

The Nags Head land development plan of July 1964[1] recommends consideration of a municipal cost-sharing program for dune protection. It is also suggested that a hurricane building code be adopted and that provision be made for personnel to inspect buildings during the course of construction. The Nags Head zoning ordinance, adopted in June 1962, makes no reference to storm hazard and includes no provisions for minimum floor elevations or for keeping development out of the most vulnerable areas.

Future developments. The amount of land available for further development was sharply reduced in 1953 with the creation of the Cape Hatteras National Seashore part of which is in the study area. This has resulted in an acceleration of development outside the Seashore area and appears likely to continue to do so. The National Seashore attracts almost one million visitors annually to the area and this is likely to promote an increased phase of commercial development also.

The threat of severe and damaging storms is not likely to be a deterrent to further growth. Even in the event of a major catastrophe, it seems highly improbable that the pace of development would be more than temporily slackened. The pattern of the immediate future will depend to some degree on the choice of a few large property owners. Higher taxes are likely to encourage them to sell out before long, thus liberating more land for commercial and residential development. The four-fold increase in taxes over the past

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[1] North Carolina, Department of Conservation and Development, Division of Community Planning. Economic Function and Population. Land Development Plan for Nags Head, July 1964.

fifteen years is also encouraging the construction of large modern motels instead of cottages. The quiet and peaceful summer cottage atmosphere is rapidly disappearing. Each summer the 750 year-round population is swollen to 25,000.

Nags Head is an area of rapidly expanding coastal development for summer recreation. Although it is more exposed to severe storms than many coastal areas, development pays little or no attention to areas of greatest hazard and further rapid build-up of storm damage potential may be expected to continue, both by the extension of summer cottages into previously vacant areas, and by intensification of development with the construction of motels and other facilities for tourists and vacationers.

14. Bethany Beach, Delaware[1]

The eighth and final example of the summer shore type of coastal development is the resort community of Bethany Beach. It is located on the long sand bar that runs from Cape Henlopen to Chincoteague. Bethany Beach resort is about six miles north of the Maryland line and just over four miles south of Indian River Inlet. The study site includes 8.2 miles of Delaware coastline and extends inland for about one mile. (See figure 14 in the appendix.)

Physiography. The beach itself is straight and gentle, 100 to 300 feet wide, and is backed by low coastal dunes. These dunes have been removed near the settlements of Bethany Beach and York Beach, but in unpopulated sections they grow, with some help, to a height of a little over 10 feet.

In the southern part of the study area, the coastal dunes are connected to the mainland. In the northern section of the beach, the dunes extend as a barrier bar across Indian River Bay. Indian River Inlet is a cut through the sand barrier kept open by protective jetties. Beach and coastal dunes makes up 22 percent of the study site.

The bays, lagoons, and salt marshes that generally lie between the dunes and the mainland are a second distinct physiographic type (about 29 percent of the study site). Behind the town of Bethany Beach is the only place in the study area where this separating marshland is not found. Large sections of these marshes, all of which lie less than 10 feet above sea level, are being filled in for marinas and housing developments.

Third, there is the mainland (49 percent of the study site) which is a nearly flat terrace or plain with an average elevation of between 5 and 10 feet above mean sea level. In places, this plain is broken up into a series of necks which jut out into Indian River Bay and Assawoman Bay. Lagoons and marshes occur between the necks.

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[1] Field work by Robert Arnold and Richard Hecock. We are indebted to the following persons who provided information: Mr. J. Pophan, Mr. J. Barker, Mr. S. Bennett, and Mr. P. Short.

Materials within the study site include sand and some silt on the coastal beaches and dunes; soft muds and clays in the lagoons; and older sands and gravels with some clay, on the mainland. Sandy loam soils, also on the mainland, are usually under cultivation.

Vegetation on the dunes and barrier bars consists of scattered salt-tolerant grasses and herbaceous plants. Salt-tolerant marsh grass is found along the edges of the bays and lagoons. On the mainland, vegetation is denser with mixed forests of pine and oak which surround the open farmlands. (See cross section, figure 2-15.)

Storm hazard. The frequency of storms at Bethany Beach is relatively low but the physiography of the area makes it highly vulnerable to inundation.

Field interviews put the flood of record at about 10 feet above mean sea level. A maximum high water mark of 10.4 feet was recorded by the Coast Guard during the March 6-8 storm of 1962. Since nearly 95 percent of the study area is below 10 feet the site has been and will continue to be subject to inundation and damage from large storm waves and tides.

Before the March 1962 storm, several dune areas had grown to elevations higher than 10 feet, but these were washed away by the continued pounding of storm waves at that time. In 1963, only two small dune areas were found to be higher than the 10-foot contour.

Settlement history.[1] The earliest settlement in the vicinity was at Lewes in the lee of Cape Henlopen, established by the Dutch in 1631. Subsequently English settlers also moved in, and during colonial times, the bays and lagoons behind the coastal sand bar were noted for oysters, clams, fish, and waterfowl.

It is unlikely that much use was made of the study site portion of this sand bar until close to 1900, although for two centuries the Indian River Inlet served as a gateway for small sailing vessels bringing finished products into the 150 and 200 square miles of the inner bay region. These same ships brought grain and forest products out to the coastal ports. Many of these vessels were built on the Indian River and this inlet was especially important prior to the era of railroads and paved highways.

The land on which the town of Bethany Beach now stands was owned by Cornelius Hall in the 1890's and had been in his family for approximately 150 years. He sold this land to the Bethany Beach Improvement Company.

> "In 1890 this site was picked out from others up and down the Atlantic Coast by several members of the Christian Church Disciples of Scranton, Pa., who were appointed to select a spot for the summer activities of the Christian Church Disciples of Maryland, Delaware, and the District of Columbia. Later forming the Bethany Beach Improvement Co., this group

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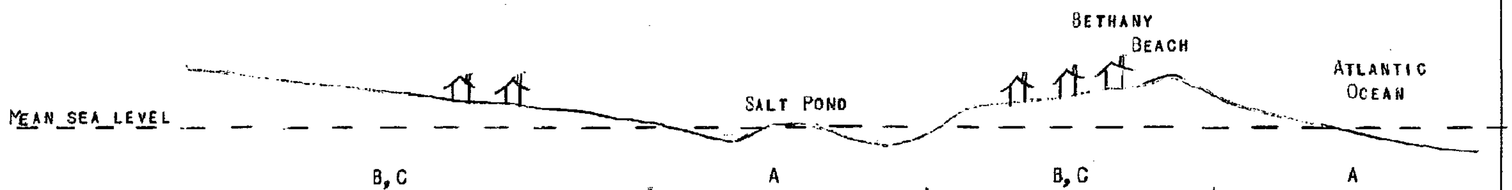
[1] Parts of this account are based on W. L. Bevan (ed.), History of Delaware, Past, and Present, Vols. I-IV (New York: Lewes Historical Publishing Co., Inc., 1929).

STUDY SITE NO. 14



ZONE	ABOVE MEAN HIGH TIDE, BUT BELOW 20-FOOT CONTOUR	BELOW MEAN HIGH TIDE	ABOVE MEAN HIGH TIDE, BUT BELOW 10-FOOT CONTOUR	BELOW MEAN HIGH TIDE
GEOMORPHIC TYPE	GENTLY SLOPING NEARLY FLAT TERRACE. OLDER SANDS AND GRAVELS	LOW TIDAL MARSH AREAS SILTS AND CLAYS	SAND DUNES ON TOP OF A NEARLY FLAT COASTAL TERRACE	WIDE SANDY BEACH AND CONTINENTAL SHELF. GENTLE GRADIENT
TYPE OF HAZARD	MINOR FLOODING TO THE 10-FOOT CONTOUR	SUBJECT TO TIDAL INUNDATION	FLOODING AND DUNE EROSION	FLOODING AND BEACH EROSION
DEGREE OF HAZARD	MINOR	MINOR	SEVERE	SEVERE
STRUCTURES	A FEW FARM HOUSES	FEW	NUMEROUS SUMMER HOMES	FEW
ADJUSTMENTS	FEW	FEW	SOME INDIVIDUAL ADJUSTMENTS WITH BULKHEADS AND DUNE PROTECTION	MAJOR THROUGH BEACH FILL AND PROTECTIVE WORKS

FIGURE 2-15. DIAGRAMMATIC CROSS SECTION, BETHANY BEACH, DELAWARE

agreed to purchase land and develop it and to provide transportation from the railroad to the isolated place, provided that the society would purchase not less than 100 lots and give "moral support."

"On July 12, 1901 Bethany Beach was formally opened and the Tabernacle dedicated. Transportation from the railroad at Rehoboth was provided by the little steamboat Atlantic across Rehoboth Bay, Indian River Bay, and up White's Creek to Ocean View, whence horse-drawn carryalls covered the last two miles to the beach. Later a ditch was dredged a mile long between the Assawoman Canal and the resort, so that boats could land at the spot. Both canal and ditch have since silted up, so that now only row-boats can approach the beach this way."[1]

The permanent population of the settlement remained small for a long time. It was about 50 in 1910 and remained the same in 1920. By 1950 it had reached 170 and today it is about 400. The town has continually been popular as a summer resort, and there was a good hotel there at least as early as 1929. Some of the religious atmosphere stemming from its origins still remains. Services are held on the church land during the summer and there is an annual meeting in June. By the terms of the deed for the resort, the sale of alcoholic beverages on any piece of property forfeits the lot back to the developers. This has helped to keep Bethany Beach as a relatively quiet resort compared with some others.

The Indian River Coast Guard Station was the most remote and inaccessible station on the Delaware Coast until the paved road, which is now route 14, was completed in 1934. During this period, most of the coastal barrier bar was state-owned land that had become dotted with squatters' cabins and huts. By 1938, the state had done nothing to evict these people and this may have something to do with the present controversy over ownership of certain sections of the study site.

The history of Indian River Inlet is interesting as construction of a new bridge is presently underway. This inlet was first bridged by a fixed-timber bridge in 1934 when the road was built. When this structure proved inadequate in its resistance to storms, a swing span drawbridge of concrete and steel was constructed in 1938-39. The inlet was partially stabilized at this time by two jetties on the ocean side of the bridge on either side of the inlet. Previously, the inlet had alternatively opened and closed and the channel had migrated up and down the coast under the influence of storms and tides.

This behavior was intensified by the digging of the Assawoman Canal about 1890 and the Lewes and Rehoboth Canal, both of which robbed water from the bay which would have kept the inlet open. (Assawoman Canal was supposed to have been an important intracoastal waterway, but traffic never materialized and the canal was allowed to deteriorate. It has been important as a drainage ditch, however.) In 1920, after a dry spell, the inlet closed completely for several years, resulting in the disruption of

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[1] Delaware, American Guide Series (New York: Hastings House, 1955).

navigation, and the destruction of all marine vegetation and the seafood industry. It also provided an excellent place for mosquito-breeding. In 1935-36, under mosquito-control auspices, mass meetings increased the pressure for opening the inlet and the District U.S. Engineer approved the project in 1937.

The presently-used bridge, built in 1938, has been damaged several times by storms and the south end was destroyed by a storm in 1948. That bridge was not reconstructed until 1951. A new bridge was under construction in the summer of 1963 which was to replace the one then being used.

Land use changes. The largest change in the study area since the first available photo coverage in 1938 is the substantial increase of cottages. Of the 1041 single family residences in the study area in 1963, 856 have been built since 1938. This is an average rate of 34 per annum. But the average rate since 1954 is 52 per annum. We estimate that nearly half of the single family residences have been built in the last 10 years.

Seafront lots in Bethany Beach itself are in short supply, and development has spread out in a ribbon north and south along the seashore. In the south, development has pushed as far as military and wildlife reservations and can proceed no further. There is still room for development at the northern end where large amounts of land are controlled by a single owner. It is not possible to predict how rapidly this land is likely to be released for cottage development.

In the southern part of the study area at the place called South Bethany, there are considerable areas of reclaimed land. Several hundred acres of marshland have been designated for residential development, and marina access canals have been constructed to enable property owners on the marsh side of the bar to have a waterfront lot.

Such developments have not yet occurred in the north, where more readily developable land is still available. Development has also occurred on either side of Indian River Inlet since the early 1950's. The houses here are of a temporary nature. Many of them are trailers, with residents holding only short-term leases to small parcels of property and access rights. Residents are permitted to make additions to the trailers, however, so that the development takes on a more permanent air.

The pattern of land use is shown in the overlay to figure 14 in the appendix. Recorded changes of land use are given in table 2-14.

Adjustments to hazard. There is a moderate degree of awareness of storm hazard at Bethany Beach and this is associated with a wide range and high rate of adoption of adjustments. The area is relatively unprotected and this has led to attempts to reduce the hazard by bulldozing sand into 10-foot high dunes and planting grass to stabilize them.

Private adjustments are very common and consist primarily of building protective works with rock rubble, bales of hay and sand bags. One respondent had made his own seawall from old railroad ties. Others reported efforts to make houses more secure by tying them down with cables.

Table 2-14

Bethany Beach, Maryland

Major Land Use Changes by Hazard Zones[1]

Zone	Land Use	No. Structures					No. Acres				
		1938	1954	% change	1963	% change	1938	1954	% change	1963	% change
A	8 Undeveloped	0	0	0	0	0	360	360	0	360	0
Tidal	Total	0	0	0	0	0	360	360	0	360	0
B	2 Commercial	32	36	+12	81	+125	6	13	+117	26	+100
	3 Public	60	71	+18	64	-10	21	90	+329	90	0
	4 Recreational	0	3	na[2]	0	na	485	586	+21	595	+2
	6a Residential	168	521	+210	957	+84	148	406	+174	607	+50
	7 Agricultural	10	10	0	10	0	215	200	-7	173	-14
	8 Undeveloped	0	0	0	0	0	2061	1638	-20	1420	-13
Tidal-10'	Total	270	641	+137	1112	+74	2936	2936	0	2936	0
C	6a Residential	17	44	+159	84	+91	5	8	+60	20	+150
	7 Agricultural	16	14	-12	16	+14	123	123	0	118	-4
	8 Undeveloped	0	0	0	0	0	50	47	-6	40	-15
10'-20'	Total	34	60	+76	104	+73	178	178	0	178	0
D											
> 20'	Total	0	0	0	0	0	Negligible				
F	2 Commercial	32	36	+12	81	+125	6	13	+117	26	+100
	3 Public	60	74	+23	64	-11	21	90	+329	90	0
	4 Recreational	0	0	0	0	0	485	586	+21	595	+2
	6a Residential	168	521	+210	957	+84	148	406	+174	607	+50
	7 Agricultural	10	10	0	10	0	215	200	-7	173	-14
	8 Undeveloped	10	0	na	0	0	2421	1998	-18	1780	-11
Flooded	Total	270	641	137	1112	+73	3296	3296	0	3296	0
All	1 Industrial										
Zones	2 Commercial	32	36	+12	82	+128	6	13	+117	26	+100
	3 Public	60	72	+20	65	-10	21	90	+329	90	0
	4 Recreational	0	4	na	1	-300	485	586	+21	595	+2
	5a Recreational	1	0	na	1	na	0	3	na	25	+733
	5b Recreational	0	0	0	0	0	0	0	0	0	0
	6a Residential	185	565	+205	1041	+84	153	414	+171	627	+51
	6b Residential	0	0	0	0	0	0	0	0	0	0
	6c Residential	0	0	0	0	0	0	0	0	0	0
	7 Agricultural	26	24	-8	26	+8	338	323	-4	291	-10
	8 Undeveloped	0	0	0	0	0	2471	2045	-17	1820	-11
	Total	304	701	130	1216	73	3474	3474	0	3474	0

[1] Minor land uses omitted and total may exceed land uses enumerated.
[2] na -- Calculation not appropriate.

Future development. There is every indication that demand for recreational opportunities will keep Bethany Beach expanding rapidly. One distinctive feature of this study site, not found to the same degree elsewhere is the waterfront lot type of development in which boat channels are constructed through subdivisions in such a way that each house fronts on a body of water, thus permitting the resident to keep his boat close to his house. Marshland areas are particularly suitable for this form of development and it appears likely to increase in the area. It is a pattern of development particularly associated with the Florida Keys and other areas further south than the shores of Megalopolis, but it is making itself increasingly felt further north. While its amenity advantages are clear, there is also a danger that in building boat channels new paths for storm waters are being created that will cause heavy damage in the future. This is especially the case where development is unregulated.

Bethany Beach is an example of rapid and continuing summer shore development in the face of a recognized storm hazard. Storm damage potential is mounting rapidly, although not without the adoption of private adjustments to attempt to reduce damage. Recent developments of marinas is pressing even closer to the mean high tide level in an uncontrolled fashion. Such developments appear likely to continue in the face of periodic setbacks in the form of storm damage, and to proceed until all available lots have been used.

The Empty Shore - The Vanishing Shore

15. Assateague, Virginia[1]

The final case study is included to represent those miles of empty coastline on the shores of Megalopolis which are rapidly vanishing under the spreading highways, marinas, motels, and summer residences. It is located immediately adjacent to Chincoteague Island, (study site No. 4).

Assateague Island is a 32-mile long barrier bar, which has been slowly extending southward from Ocean City, Maryland. Most of the barrier bar is in Maryland, but a part of the southern end in Virginia was chosen for a study site, mainly due to its accessibility from Chincoteague. For most of its length the bar is less than a mile wide, but in the southern part a series of beach accretion ridges curve to the west in the shape of a hook making the bar nearly two miles wide. (See figure 15 in the appendix.)

Physiography. Physiographically, Assateague is very similar to nearby Chincoteague Island. Both are low sandy islands subject to change in their shape and size as tidal channels and offshore currents move the unconsolidated sands and clays from one place to another.

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[1] Field work by Mr. Robert Arnold and Mr. Richard Hecock. We are indebted to the following persons who provided information: Mr. Roy Tolbert and Mr. Charles Noble.

Assateague is a shifting barrier bar with a long, nearly straight, gently sloping, sandy beach, 200 to 300 feet wide. Behind the beach are a series of sand dunes, sand plains, and tidal marshes, which represent earlier shorelines. The sand dune ridges trend parallel to the present shoreline and have hooks at the south which parallel the present hook that is growing south and west very rapidly. The entire barrier bar is made up of wind-blown sand with some silt and clay in the marshes and lagoons. The silts and clays are found between the sand ridges and on the lagoon side of the barrier bar. About 46 percent of the study site is made up of sand ridges and swales, and 54 percent consists of marshland.

The largest dunes, which reach a height of 47 feet, occur on the west side of the bar. The dunes and ridges are the only part of Assateague which escaped flooding during the March, 1962 storm. This higher ground was where the Assateague ponies took refuge. Pines are found on the ridges and grasses in the low areas. The Fish and Wildlife Service plants grass in closed off fresh water ponds for the migrating birds. (See cross section, figure 2-16.)

Comparison with other study sites. The landforms found at the Chincoteague and Assateague study sites are in many ways similar to the Nags Head study site. The barrier bar at Nags Head is similar to the barrier bar at Assateague. Chincoteague Island can be compared to Roanoke Island. The tidal marshes and lagoons are similar at the two sites, but Chincoteague Bay is not as large as Pamlico Sound.

However, none of the study sites have such a complex of ridges and swales as on Chincoteague-Assateague. Also, the dune ridges on Assateague are lower and more stabilized by vegetation than the larger migrating dune masses at Nags Head.

The rapid growth of Assateague barrier bar at the tip can be compared with the tip of the Sandy Hook region of northern New Jersey.

Storm hazard. Both flooding and beach erosion occur at Assateague. The 10-foot elevation for the flood of record ascertained from field interviews at Chincoteague can be applied to Assateague also. During the March 1962 storm most of the southern part of Assateague Island was flooded except for the small, narrow dune ridges on the west side of the bar which are 20 to 40 feet above mean sea level.

Coastal changes. Both Assateague and Chincoteague are subject to sudden and severe coastal changes during large storms. Generally 100 feet of sand is removed per year along the 32-mile length of barrier bar. This sand is being deposited at the southern tip of Assateague where a large hook is growing both south and west, about 100 feet per year.

Assateague is, in places, a very narrow bar. At times during storms, inlets will be cut through the island to the bays. The opening and closing of these inlets is a normal process for outer bars. During a storm in 1933, an inlet was cut through Assateague south of Ocean City, Maryland, and this has been kept open with a series of permanent jetties.

Past storms. Both hurricanes and northeasters have caused damage at Assateague. Of the 35 damaging storms recorded along the Virginia coast in the past 40 years, 19 have been hurricanes. The greatest amount of damage was caused by the hurricanes of the 1930's and by the non-hurricane storm of March 6-8, 1962.

During the 1962 storm two persons were drowned and three other injured when an 83-foot fishing trawler was grounded on Assateague. It was also reported that about 150 of the famous wild ponies were drowned.

Settlement history and land use. There is no permanent settlement on Assateague Island within the study area. Land use data are incorporated with those for Chincoteague in Study No. 4.

The Assateague study site is made up almost entirely of the Chincoteague National Wildlife Refuge which was established in 1943 and includes 9,000 acres of Assateague Island in Virginia. It is located directly on the Atlantic flyway for migratory birds and hundreds of species regularly visit the area.

Assateague is famous for its wild ponies. According to legend a Spanish ship containing ponies was wrecked off the coast of Assateague in the 16th century. The ponies that survived came ashore on the island. Since only Chincoteague was heavily wooded at that time the ponies eventually made the narrow crossing between the two islands. Ponies have been on both islands right up to the present time and have long served as a tourist attraction.

One significant change on Assateague is the conversion of a portion of the Wildlife Refuge into a public recreation area. This recreation area is leased from the Fish and Wildlife Service by the Chincoteague Bridge and Beach Authority.

Other parts of Assateague Island to the north are threatened with development, but this will change if the seashore proposal is passed. In any event at the southern end, the public ownership of land is likely to prevent intensive development and the area will probably be preserved as public open space in perpetuity. There are few such areas left on the shores of Megalopolis.

STUDY SITE NO. 15

	A	B, C, D	A, B	B	A
ZONE	BELOW MEAN HIGH TIDE	ABOVE MEAN HIGH TIDE TO ABOVE 20 FEET	BELOW MEAN HIGH TIDE TO LESS THAN 10 FEET	ABOVE MEAN HIGH TIDE, BUT BELOW 10 FEET	BELOW MEAN HIGH TIDE
GEOMORPHIC TYPE	TIDAL MARSH AND TIDAL CHANNEL	LINEAR DUNES OVER 20 FEET HIGH, WIDE EXTENSIVE SANDY FLATS	LOW FLAT LANDS WITH SOME TIDAL MARSH	LOW SAND DUNES	WIDE BEACH WITH GENTLE GRADIENT
TYPE OF HAZARD	TIDAL INUNDATION AND CHANNEL EROSION	SOME FLOODING	FLOODING	DUNE REMOVAL	BEACH EROSION AND FLOODING
DEGREE OF HAZARD	MODERATE	MINOR	SEVERE FLOODING	SEVERE FLOODING AND EROSION	
STRUCTURES	NONE	ONLY 2 OR 3	NONE	FEW	NONE
ADJUSTMENTS	FEW	MINOR	NONE	FEW	NONE

FIGURE 2-16. DIAGRAMMATIC CROSS SECTION, ASSATEAGUE, VIRGINIA

CHAPTER III

CLIMATOLOGY OF DAMAGING STORMS

Introduction

In any study of human adjustment to hazards, it is necessary to have detailed information on the actual occurrence of the hazard in order to evaluate the significance of the human response. Inhabitants along the coast have achieved a certain degree of awareness of the hazards of coastal living, of the frequency of damaging storms, of the likelihood of future damage from wind and waves. This awareness is based in part on their own experience under storm or damage conditions and in part on other economic, social, cultural, and educational factors. The relative importance of these factors and the relevancy of any program to control or mitigate future damage can only be determined by comparing human perception and understanding with actual occurrence. It is in the discrepancies, those cases where reality confutes perception, that control programs will fail or humans will initiate action that will be detrimental to themselves or to their environment. In our present context, therefore, it is important to have a good understanding of the actual occurrence of coastal storms, the frequency of damage from wind and waves, the nature of the damaging storms, and the changing pattern of damage both in time and in space if we are to interpret the real significance of the human response. The following chapter seeks to outline something of the climatology of damaging storms that affect the east coast of the United States.

General Statement of Approach

The damage potential of a storm of a given intensity depends very much on a large number of physical factors. Some coastal sites may be more vulnerable than others by virtue of elevation, height of tide, aspect or orientation with respect to the storm surge and waves, offshore bottom conditions, the condition of natural and man-made coastal defenses, type and pattern of human development, and other factors. Proximate sites may differ markedly in vulnerability due to one or a combination of these factors of which we have only a very general understanding.

For this reason, it is extremely difficult to determine the vulnerability of particular sites along the coast. It is possible to develop a notion of the relative storm hazard for different portions of the coast by examining the history of damage during the past several years. In doing this it is necessary to remember that the damage caused by a storm is taken as a measure of the storm's intensity. This has been done in an effort to integrate the many independent meteorological and other factors, including astronomical tide, that in combination determine the destructive potential of a given storm. Inherent in this procedure is that its usefulness is limited to the broad scale of time and space; that is, that while our approach should show the broad pattern of hazard as it differs along the coast and has changed in time, the analysis will not be especially useful for understanding the hazard at particular sites. For the latter, detailed historical and physical studies of each site would be required. Such detailed studies of individual sites would, of course, be difficult to use for purposes of generalization because of the variability in the experience of neighboring sites.

The approach we have adopted has sought to identify the over-all pattern of storm damage on the east coast of the United States; to classify the sorts of meteorological conditions that are responsible for coastal damage; to determine where along the coast damage (or the likelihood of damage, in the absence of actual reported damage) is most frequent; how this frequency of damage has changed in the past several decades; and to determine as far as possible whether the observed changes in damage frequency during the years are due to meteorological changes or changes in human use (or abuse) of the coast.

Frequency of Coastal Storms

Records of coastal storms and related damage during the past 44 years are contained in a number of different periodicals, newspapers, and weather summaries. As the method of reporting such storms, the reporting group, and the public interest have all changed, so also have the sources of data. The prime sources for all storm data during the period 1921-1964 have been U.S. Weather Bureau climatological publications. From 1921 until the end of 1949, brief records of severe storms were published in the Monthly Weather Review, while more detailed articles on storms of significance were included in the Review itself when warranted. From 1950 until the end of 1958, these storm records were included in the publication Climatological Data, National Summary. Since 1959 a much more expanded record of all severe storms has been published monthly in the special report entitled Storm Data.

In order to supplement these records, several other sources have been used for varying periods of time. Included among these are the Mariner's Weather Log, Weekly Weather and Crop Bulletin, Weatherwise, New York Times, and various articles in periodicals.[1] The record of hurricane damage over the past half century is particularly

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[1] For example: A. I. Cooperman and H. E. Rosendal, "Mean Five-Day Pressure Pattern of the Great Atlantic Coast Storm, March 1962," Mon. Wea. Rev., 91, 337-344, 1963; D. L. Harris, "Coastal Flooding by the Storm of March 5-7, 1962," U.S. Wea. Bur., Manuscript, 22 pp, 1963; R. H. Simpson, "The Unique Development of the Severe Atlantic Coastal Storm, March 1962," paper presented at 211 Nat. Meeting, AMS, 11 pp, 1963; D. M. Thomas and G. W. Edelen, Jr., "Tidal Floods, Atlantic City and Vicinity, New Jersey," Hydrologic Invest., Atlas HA-65, U.S Geol. Survey, 1962; U.S. Weather Bureau, "Criteria for a Standard Project Northeaster for New England North of Cape Cod," Memo Hur. 8-5, Hydrometeor. Sec., Hydrol. Ser. Div., 91 pp, 1963.

well documented[1], but such storms constitute only about one-third of the total that has resulted in damage to the coastal areas.

While the portion of this study dealing with the human response to storms has been confined to the coastal area from North Carolina to New Hampshire, the climatological study has been expanded to include the whole east coast from Key West, Florida, to Maine since the data for the additional areas were directly available with no appreciable increase in effort. Storms affecting the Gulf of Mexico area, including the west coast of Florida, have not been included. This climatological study was primarily concerned with damage that resulted from the peculiar conditions existing at the sea coast (wave damage, coastal flooding, and tidal inundation) so that storms which caused damage only by wind or precipitation were not included.

Figure 3-1 gives the yearly record of all storms that have brought at least some water damage to part of the Atlantic coastal margin during the period 1921 to 1964. The record shows a marked increase in the number of damage-producing storms in the past two decades. From 1921 until the late 1930's, there was fairly even distribution of coastal storms, averaging two to three a year. Actual numbers ranged from one in 1921, 1923, and 1938, to a maximum of seven in 1933. During the four years from 1939 through 1942, only one damage-producing coastal storm was reported in the sources studied.

During the 1940's the number of coastal storms increased from two in 1943 and 1945 to seven in 1947 and 1950. The average for this period is slightly higher than for the pre-1938 period, although the range of variation is consistent with the earlier period. Beginning in 1950, however, a new pattern of storm frequency has seemed to develop. During the past 15 years, the minimum number of yearly storms has been five (1952-1955), while the maximum numbers have been twelve in 1962 and thirteen in 1958. The average number of storms per year for this period has been nearly eight compared with two to three during the 1920's and 1930's. Because of the type of record that is available, it is not possible to say whether this change in storm frequency is only the result of random climatological variation. It is certainly possible that the great increase in coastal occupancy and the resulting importance of damage-producing storms has led to a certain bias in reporting. This question will be considered in more detail in a later section.

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1 For example: E. M. Ballenzweig, "Fluctuations in Frequency of Tropical Storms," Weatherwise, 10, 121-125, 1957; C. W. Brown, "Hurricanes and Shore-Line Changes in Rhode Island," Geogr. Rev., 29, 416-430, 1939; G. W. Cry, W. H. Haggard, and H. S. White, "North Atlantic Tropical Cyclones," Tech. Paper 36, U. S. Wea. Bur., 214 pp, 1959; A. D. Howard, "Hurricane Modification of the Offshore Bar of Long Island, New York," Geogr. Rev., 29, 400-415, 1939; C. P. Mook, "Hurricanes Entering U. S. Mainland - Eastport to Hatteras, 1635-1955," Weatherwise, 9, 125, 1956; D. L. Harris, "Characteristics of the Hurricane Storm Surge," Tech. Paper 48, U. S. Wea. Bur., 139 pp, 1963; C. B. Carney and A. V. Hardy, "North Carolina Hurricanes," U. S. Wea. Bur., 26 pp, 1962; and D. M. Ludlam, "Early American Hurricanes 1492-1870," The History of American Weather, No. 1, AMS, 198 pp, 1963.

Classification of Storms Affecting the Coast

Study of the daily synoptic charts for each of the 195 storms that occurred during the 1921-1964 period shows that certain weather situations recurred many times. One obvious meteorological situation frequently associated with coastal damage was the hurricane. It appeared possible to classify all listed coastal storms into one of eight different types on the basis of their origin, structure, and path of movement as follows:

1. Hurricanes and severe tropical storms.

2. Wave developments forming in the Atlantic Ocean well east of the United States mainland or in the vicinity of Cuba.

3. Wave developments along cold or stationary fronts over the southeast coastal states or in the Atlantic Ocean just off the southeast coast.

4. Wave developments along cold or stationary fronts in the Gulf of Mexico forming west of 85 W longitude.

5. Depressions moving across the southern half of the United States that intensify upon reaching the Atlantic coast; no secondary development ahead of the storm center.

6. Depressions which develop as strong secondary cyclonic disturbances along the coast (often in the Hatteras area) ahead of a trailing wave or occluded center.

7. Intense cyclonic storms whose origin and entire path of movement are over land surfaces so that the low center remains west of the coastal margin.

8. Strong cold fronts accompanied by squall lines and severe local weather.

In addition, there were six storms with such diverse characteristics that they could not be grouped into any of the eight categories above. Since, in each case, the damage done by these storms was very small, they need not concern us further in the present study.

The above classes do not have sharp boundaries, and there are certain cases where storms fall near the border of divisions. Even within the classes, behavior of storms is variable; yet there seems to be sufficient consistency among the storms within a class and enough difference between classes to justify the present breakdown. In the present classification, the class 2 and 3 storms which form in the Atlantic are similar to Miller's type A cyclones[1], while the class 6 storms correspond to his type B cyclones.

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[1] J. E. Miller, "Cyclogenesis in the Atlantic Coastal Region of the United States," J. Meteor., 3, 31-44, 1946.

FREQUENCY OF DAMAGING COASTAL STORMS
EASTERN UNITED STATES, 1921 - 1964

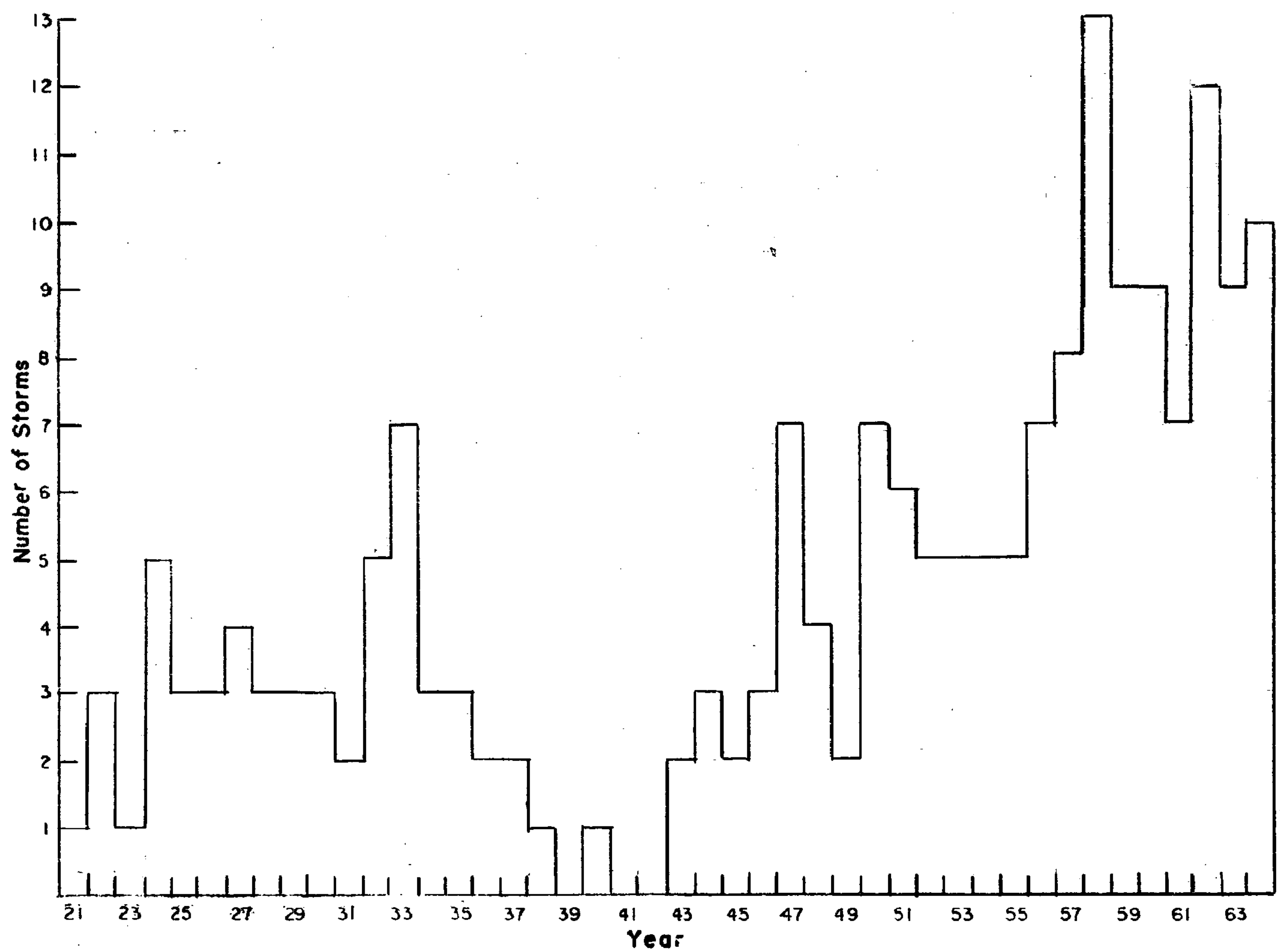

Figure 3-1

Austin[1] has also discussed conditions which are favorable for cyclogenesis along the east coast. Both his situation 1 and situation 2 cyclogenesis conditions correspond with class 3 storms as listed here. Descriptions of the different classes as well as sample weather maps illustrating synoptic conditions during each major storm class follow.

1. The unique characteristics of hurricanes are well known. Hurricanes possess higher wind velocities than other storms that affect the east coast. Their destructive power is great, although from the descriptive records of damage, hurricanes do not generally appear more severe than many class 2 storms. This is undoubtedly related to the more rapid movement of many hurricanes and to the relatively small diameter of the storms which result in shorter over-water fetch of the winds and, hence, less opportunity for wind-driven waves to pile up along the coast. During the period of record, 62 hurricanes brought damage to some part of the Atlantic coast. The synoptic charts of figure 3-2, showing the movement of hurricane Donna on three successive days in September 1960 along the east coast of the United States, are fairly typical for storms in this class.

2. Storms of the second class include waves that develop into storms at some distance east or south of the continental United States in the Atlantic Ocean or in the vicinity of Cuba. With such late-forming depressions, the high pressure system north of the storm center has moved far enough eastward to block the northeasterly movement of the storm center. This results in very slow-moving depressions that often have a pronounced east-west elongation. This configuration of the isobars will, in turn, lead to a long over-water fetch of the winds and the build-up of significant wind-driven waves along the coast. As a result, this group is probably the most destructive of all of the storms that influence the coast. Figure 3-3 is an example of an intense class 2 storm that occurred in January 1956. There were nine storms in this class during the 44-year period of record.

3. Class 3 storms include waves that form over the southeastern coastal states or in the Atlantic Ocean fairly close to the coastal margin. These storms are also frequently blocked by high pressure systems pushing eastward north of the low center. Often a pronounced east-west orientation of the isobars results from the juxtaposition of the low center and the blocking high. In both the class 2 and 3 storms, the actual damage may result as much from the pressure gradient around the intense blocking high and the long east-west orientation due to the high as from the gradient around the low itself. Figure 3-4 shows a portion of the synoptic charts for three days in November 1953 illustrating the development and movement of a class 3 storm. There were 27 storms in this class during the 44-year period of study.

4. Class 4 storms include depression originating in the Gulf of Mexico west of 85 W longitude. These storms as well as class 3 storms originate as waves that often develop on the front marking the leading edge of a strong, cold mass of cP air moving

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[1] J.M. Austin, "Favorable Conditions for Cyclogenesis near the Atlantic Coast," Bull., Amer. Met. Soc., 22, 270, 1941.

southward from continental United States. The storms usually move eastward across Florida and often strengthen as they reach the Atlantic Ocean. Since they are seldom blocked, these storms generally move up the coast quite rapidly. Often they are pushed out to sea by the surge of high pressure which moves southeastward behind the storm center. Figure 3-5 illustrates the development and movement of a typical class 4 storm during mid-February 1960. During the period of investigation there were 25 storms of this type that brought damage to the east coast.

5. Class 5 storms are relatively few in number. The original cold front ahead of a mass of cP air moves eastward from the central part of the country and out in the Atlantic. Cyclogenesis occurs on the front before it reaches the coast. As the low center moves over the ocean, deepening occurs, The center then generally moves fairly rapidly eastward or northeastward. There were only 15 storms of this class which produced damage to the coastal areas during the 44-year period of record. Figure 3-6 shows the pattern of development of a typical class 5 storm in January 1961.

6. Class 6 storms are a more complex group. In general, cyclogenesis occurs in the vicinity of the coast on a warm or stationary front emanating from a parent cyclonic disturbance to the west. With the rapid development of the coastal secondary, often in the region of Cape Hatteras, the parent depression over the continental area fills and dissipates. Wave development over the coastal area can be most rapid, but generally the storm center moves rapidly northeastward so that damage is minimized. Figure 3-7 is an example of a March 1962 storm in this class. Twenty-six storms of this type have resulted in damage to the coast since 1921.

7. Class 7 storms consist of disturbances which generally move northward over the Great Lakes and down the St. Lawrence River valley. These storms are usually highly developed and often move rapidly. Damage results when a strong pressure gradient develops between the storm center and a high pressure system to the east. There are 17 storms in this category. Figure 3-8 shows a typical example of the occurrence and development of one of these storms during a period in early February1960.

8. Class 8 storms consist mostly of severe local storms accompanying squall lines that are associated with strong cold fronts. There are no well-developed cyclones associated with most of these storms and the damage produced is generally localized and relatively unimportant. There were eight storms in this class during the 44-year period of study.

Only rough estimates of damage from coastal storms are possible. In certain cases, broad ranges of dollar amounts of damage are available in published form. More usually, only general descriptive accounts of the storm and the resulting damage are available. From this information, it has been possible to divide estimated damage into three broad classes: low, moderate, and severe. Assigning 1 for low damage, 2 for moderate damage, and 4 for severe damage conditions[1], it is possible to obtain a rough

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[1] Actual damage amounts increase more nearly geometrically than linearly as storm intensity increases. Severe damage conditions thus should be emphasized in relation to low and moderate damage conditions.

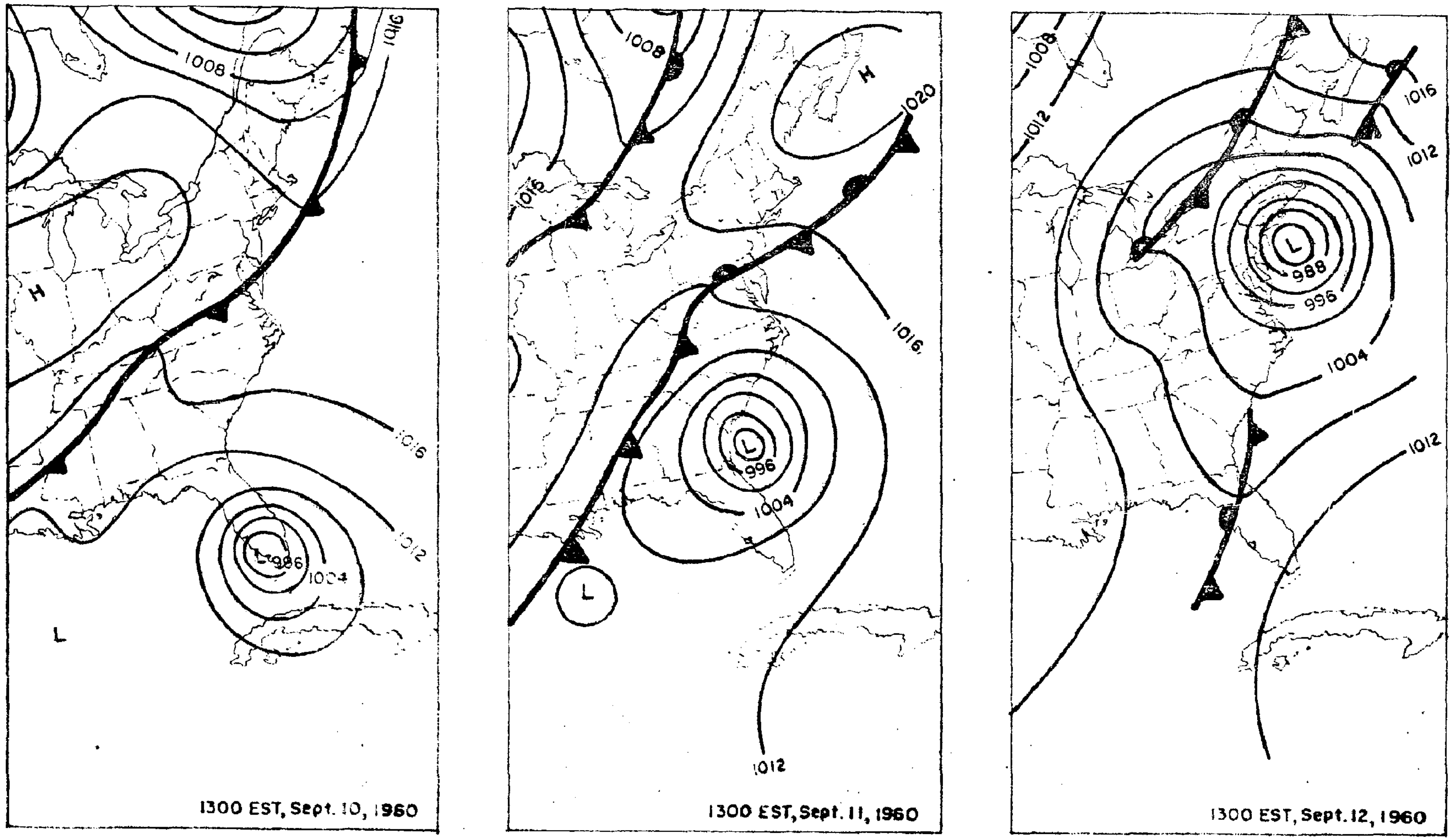

Figure 3-2. Development and movement of typical class 1 storm along east coast of the United States, 10-12 September 1960.

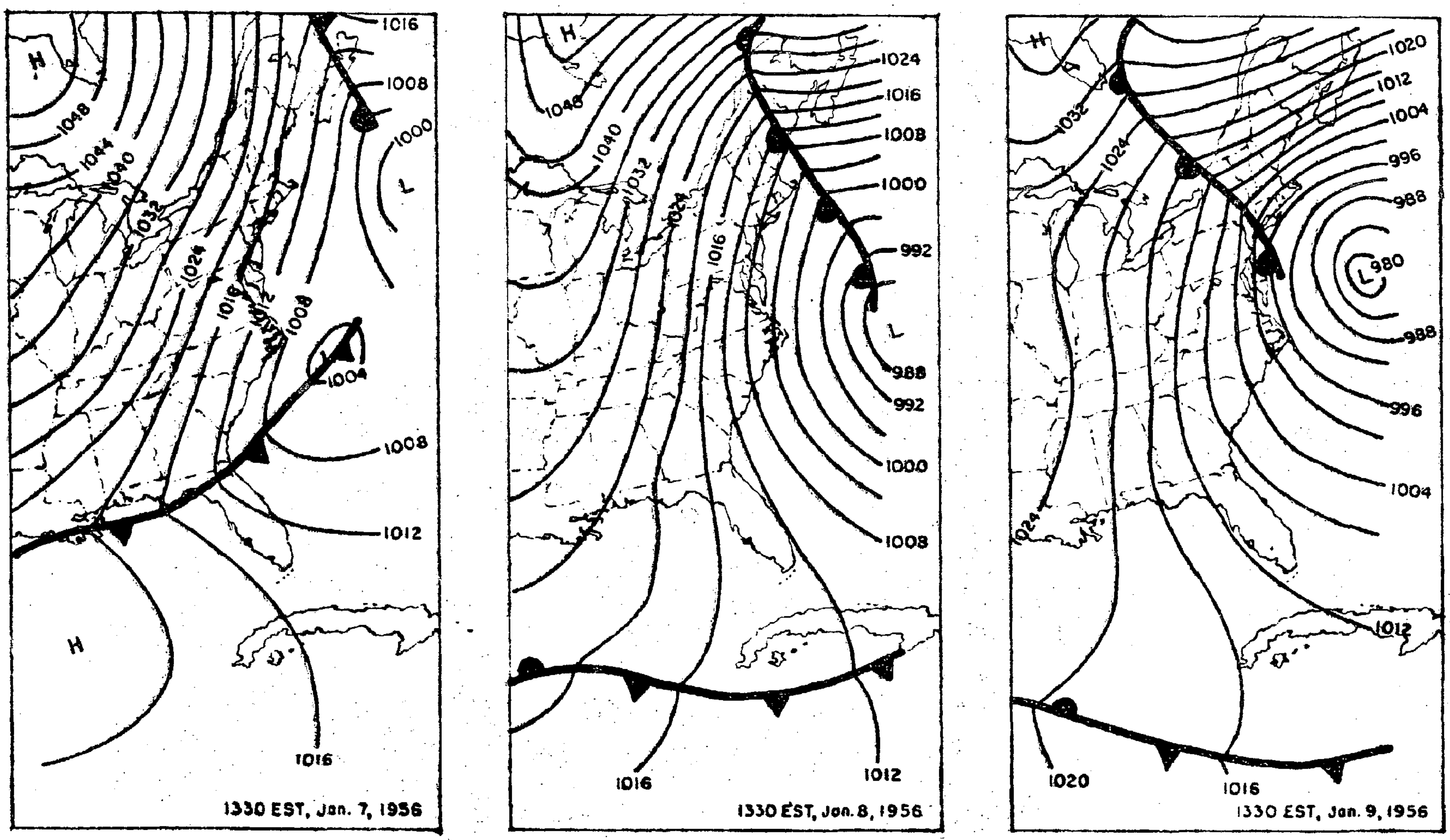

Figure 3-3. Development and movement of typical class 2 storm along east coast of the United States, 7-9 January 1956.

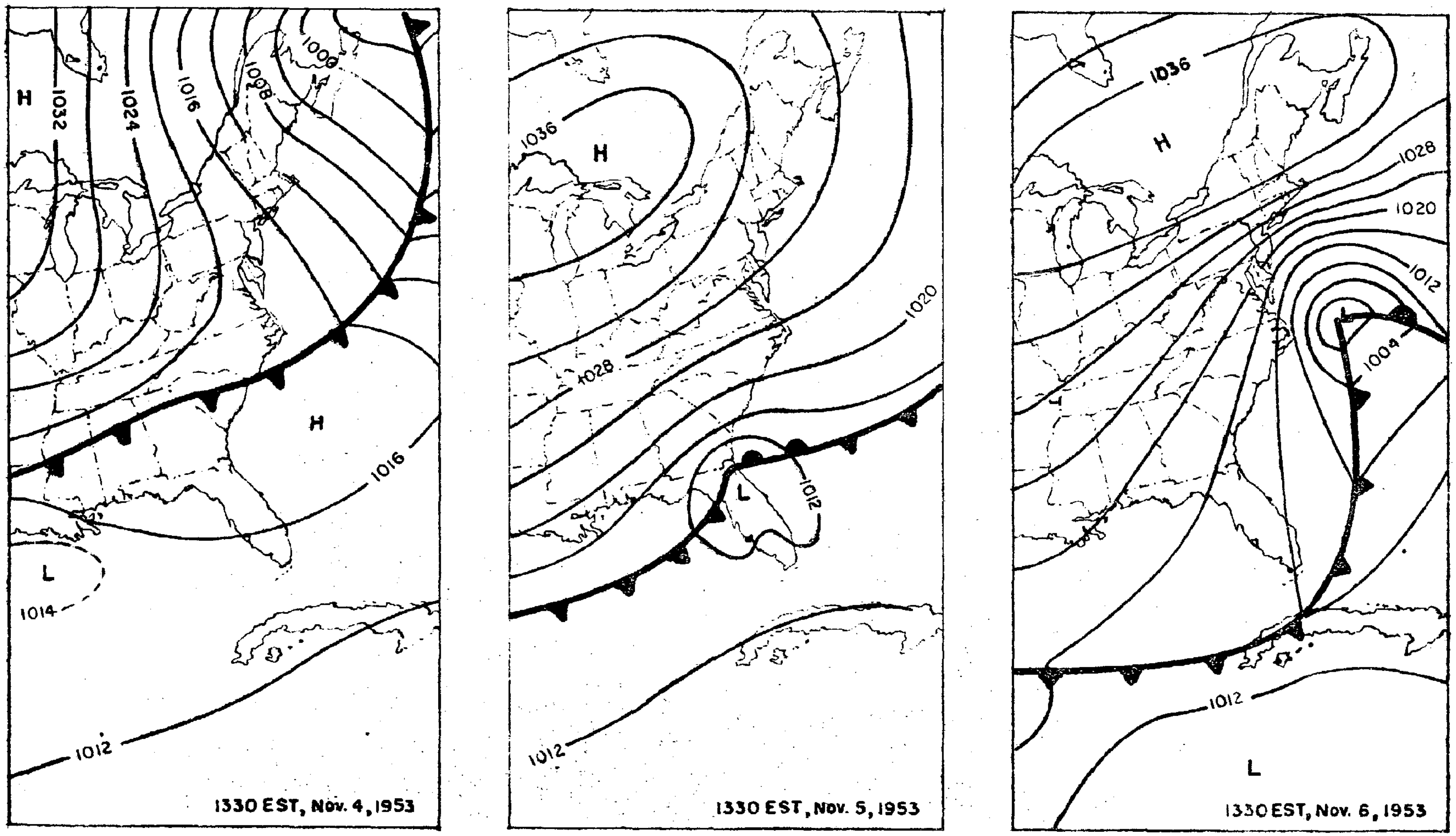

Figure 3-4. Development and movement of typical class 3 storm along east coast of the United States, 4-6 November 1953.

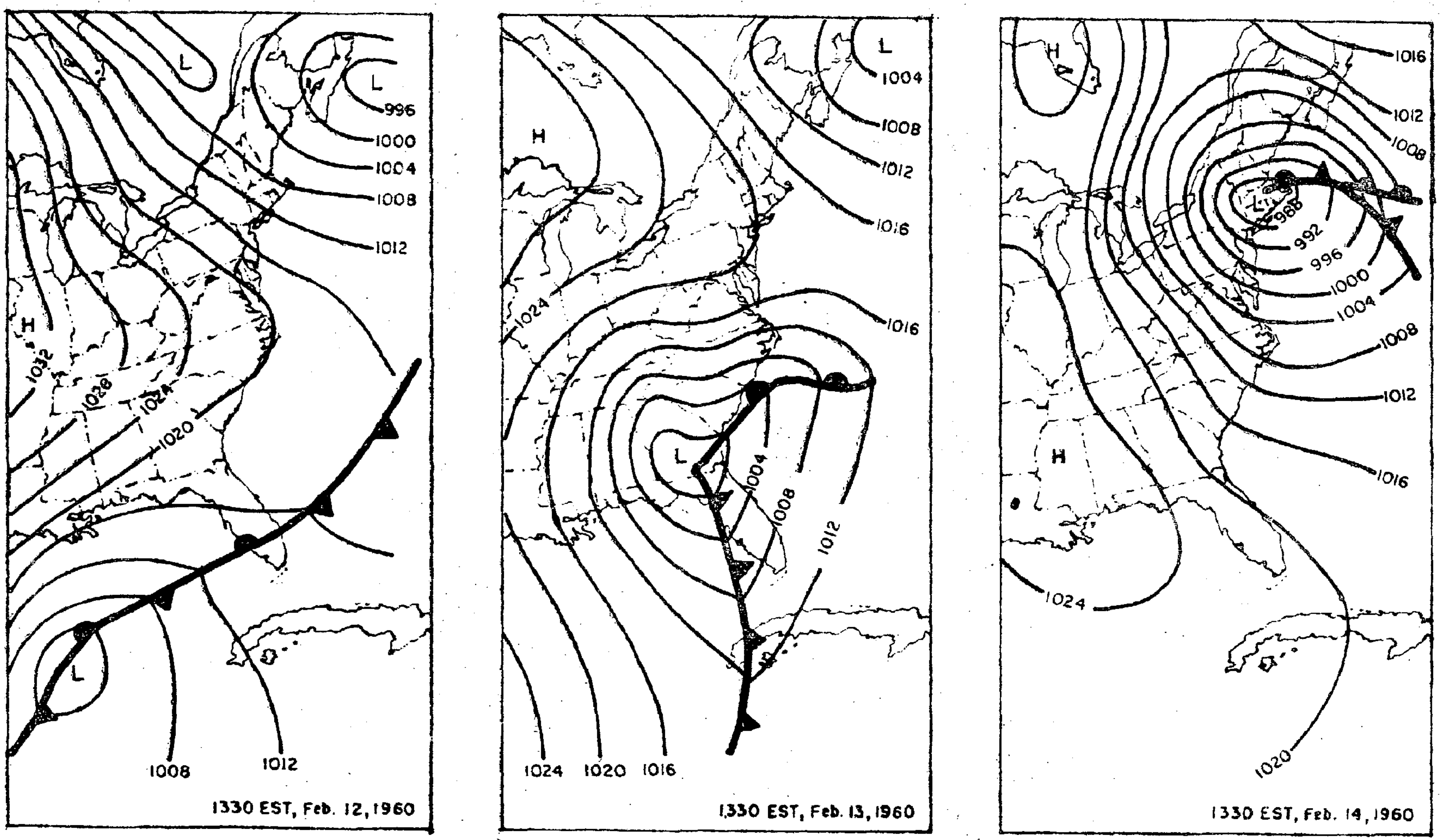

Figure 3-5. Development and movement of typical class 4 storm along Gulf and east coast of the United States, 12-14 February 1960.

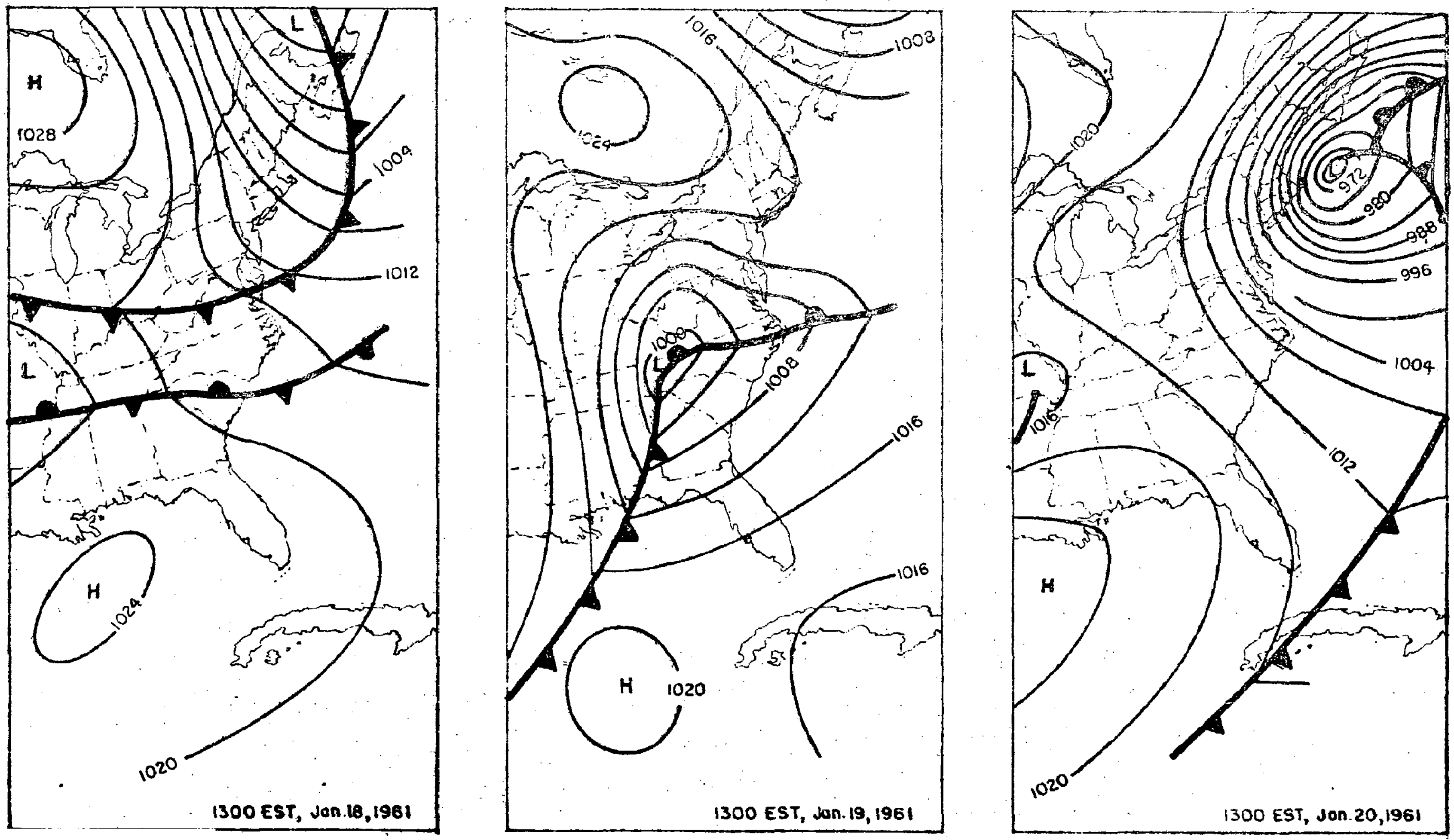

Figure 3-6. Development and movement of typical class 5 storm along east coast of the United States, 18-20 January 1961.

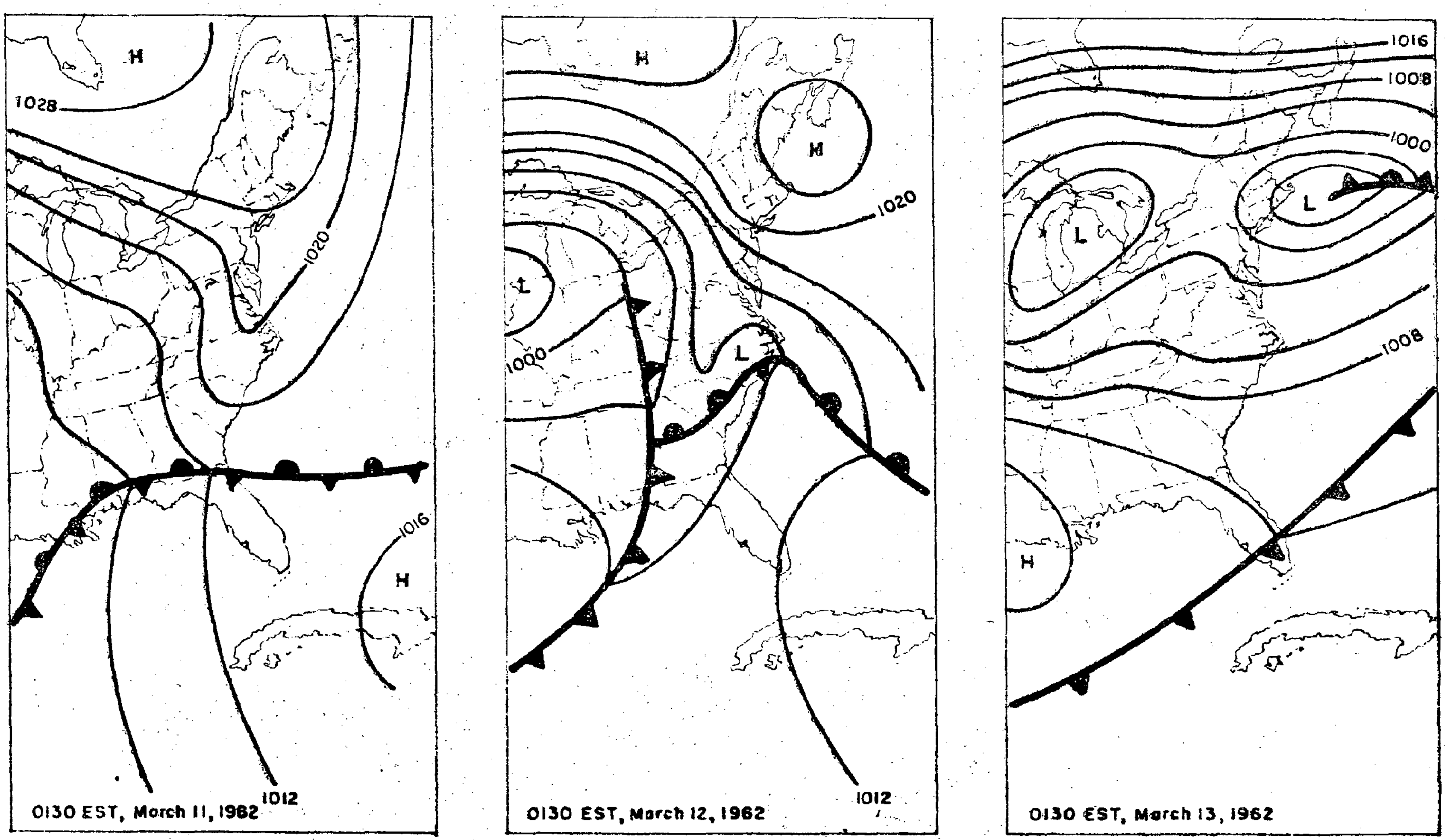

Figure 3-7. Development and movement of typical class 6 storm along east coast of the United States, 11-13 March 1962.

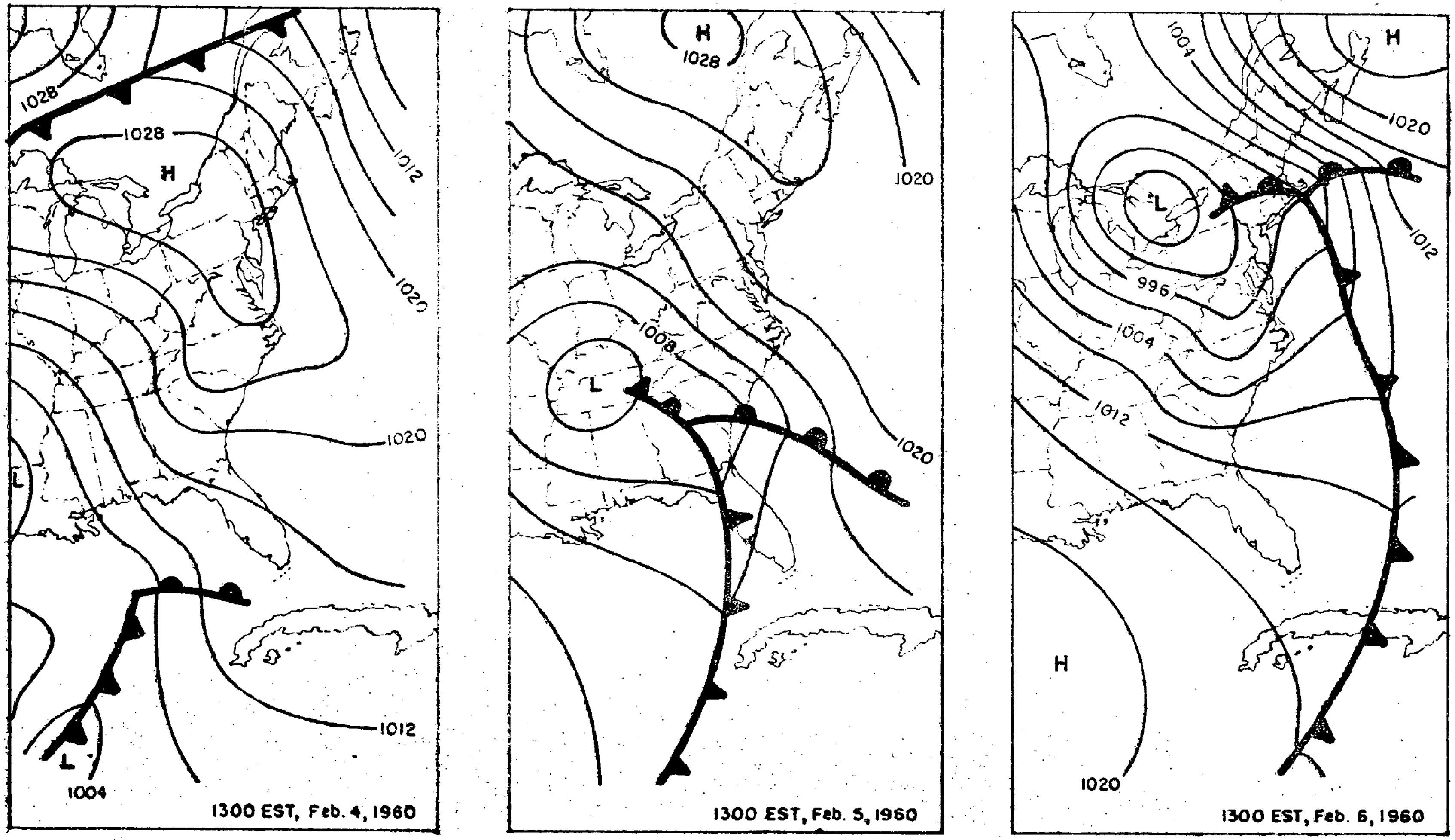

Figure 3-8. Development and movement of typical class 7 storm along east coast of the United States, 4-6 February 1960.

estimate of the average severity of each of the foregoing classes of storms. Table 3-1 shows that class 2 storms are the most severe on the basis of this qualitative interpretation of the record, followed by class 1 and class 3 storms. Class 8 storms resulted in the lowest amount of coastal damage.

Table 3-1

Frequency and Damage Estimate by Storm Type,
Atlantic Coast, 1921-1964

Class of Storm	Total Number	Damage Estimate
1	62	2.40
2	9	2.89
3	27	2.18
4	25	2.00
5	15	1.64
6	26	1.84
7	17	1.44
8	8	1.00

Table 3-2 gives the seasonal frequency of storms of different types. The seasonal maximum of class 1 storms comes as expected in September, with a range of occurrence from June through November (except for one in February). Both class 2 and 3 storms are more frequent in the fall and early winter. While class 4 storms do occur in the fall and winter, the maximum of these storms occurs in March. Class 5 storms occur mainly from November through April, although two summer occurrences have been noted. Class 6 and 7 storms are also most frequent in the winter and early spring, while class 8 storms seem to favor the late summer although the number of storms is so low that the distribution is not significant.

Table 3-2

Seasonal Occurrence of Storms by Class

Type	J	F	M	A	M	J	J	A	S	O	N	D	Y
1		1				1	3	15	24	15	3		62
2	2							1		2	3	1	9
3	3	1	2	1	1	1		3	4	5	6		27
4	2	4	5	3	2				2	2	3	2	25
5	2	3	2	1		1		1			3	2	15
6	3	4	3	5	1	1				1	4	4	26
7		3	3	1	1					3	4	2	17
8	1				1		1	1	3	1			8
Total	13	16	15	11	6	4	4	21	33	29	26	11	189

Areal Distribution of Coastal Storms

In a hearing before the Congress following the storm of March 5-8, 1962, Simpson[1] estimated that some portion of the Atlantic coast would experience appreciable storm damage about once in four years. He further pointed out that there had been ten storms since 1900 which compared in severity to the March 5-8, 1962 storm. Any one locality on the coast might experience a storm of the severity of the March storm about once in 30 to once in 60 years.

These figures give the impression of a relatively infrequent occurrence of coastal storms. While there is the qualification that the figures apply to storms of like severity to the disastrous storm of March 1962, this is often overlooked or misunderstood. It would be useful to both coastal dwellers and builders to have information on the total number of storms that have produced some damage to the coast. At the same time, knowledge of the specific coastal areas subject to repeated damage would be desirable. It is, of course, important to know that, on the long-term average of once in every 30 years a very severe storm will bring extensive damage not only to a particular area but to the whole coastal margin. It may be of even greater significance, however, to know that an area has experienced 20 storms in 30 years that resulted in some damage to houses, streets, power lines, or commercial establishments. The individual who lives along the coastal margin may experience damage or loss from any of the 20 storms in 30 years. He will almost certainly experience some damage or loss from the once-in-30 years storm. His over-all chance of damage and loss is greater than once in 30 years because of the possibility that one or more of the smaller storms causing only localized damage will affect him particularly.

Table 3-3 lists by states the number of coastal storms resulting in some reported damage during the 1921-1964 period. The storms have been separated by class as well as geographically by states. The data show that the northern part of the coastal margin has experienced a considerably greater number of storms than the southern part. Coastal Massachusetts has experienced 88 damaging storms during this 44-year period, or two per year, while New Jersey, Maine, Rhode Island, and Connecticut follow in that order. On the other hand the coasts of Georgia, Delaware, and South Carolina have experienced the fewest damaging storms, less than once every other year for Georgia and Delaware. Florida, with its long coast line exposed to hurricanes and other tropical disturbances, has experienced slightly fewer storms than has New Hampshire, with only a short coast line in an area removed from the general hurricane track. The more exposed location of North Carolina is clearly revealed, since it experiences slightly more than one damaging storm every year in contrast to one damaging storm approximately every two years for South Carolina and Georgia. Of course, this pattern of distribution says nothing of the severity of the storms involved.

Table 3-4 includes a breakdown, by states, of the number of storms resulting in severe, moderate, and light damage that have affected the coast. This qualitative

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[1] See page 10 of U. S. House of Representatives, "Improvement of Storm Forecasting Procedures," Hearing before Subcommittee on Oceanography, Merchant Marine and Fisheries, 87th Congress, 111 pp.

Table 3-3

Number of Damage-Producing Storms, by Class and State, 1921-1964

State/Class	1	2	3	4	5	6	7	8	Total	Storms per Year
Maine	9	5	9	13	6	5	8		55	1.25
New Hampshire	8	2	8	11	3	5	4		41	.93
Massachusetts	22	4	14	16	7	14	7	4	88	2.00
Rhode Island	11	1	10	10	6	12	3	1	54	1.23
Connecticut	11	1	7	10	5	10	5	1	50	1.14
New York	11	1	10	8	4	9	4		47	1.07
New Jersey	18	3	10	8	4	8	4	1	56	1.27
Delaware	8	1	5	4	1	2			21	.48
Maryland	12	1	5	4	2	2		2	28	.64
Virginia	22	1	7	7		1			38	.86
North Carolina	27	3	5	8	3				46	1.05
South Carolina	19	1	3	2		1			26	.59
Georgia	16		1	2					19	.43
Florida	26	5	5	2					38	.86

Table 3-4

Intensity of Coastal Storms and Recurrence Interval for Storms Bringing Moderate and Severe Damage, by State, 1921-1964

	Numbers of Storms			Average*	Mean Recurrence
	Light	Moderate	Severe	Severity	Interval (years)
Maine	25	24	6	1.76	1.5
New Hampshire	15	21	5	1.88	1.7
Massachusetts	31	46	11	1.90	.8
Rhode Island	24	24	6	1.78	1.5
Connecticut	22	23	5	1.76	1.6
New York	14	24	9	2.09	1.3
New Jersey	25	26	5	1.73	1.4
Delaware	7	13	1	1.76	3.1
Maryland	13	14	1	1.61	2.9
Virginia	11	22	5	1.97	1.6
North Carolina	14	23	9	2.09	1.4
South Carolina	7	15	4	2.04	2.3
Georgia	5	14	0	1.74	3.1
Florida	7	21	10	2.34	1.4

* Based on 1 for light damage, 2 for moderate damage, and 4 for severe damage.

assessment of damage has again been made on the basis of available descriptions. In this case, average severity does not vary greatly from state to state, ranging from 1.61 for Maryland, to 2.34 for Florida. There seems to be a tendency for the southern states to be influenced by storms of greater severity, although the number of storms per state is generally greater for the northern part of the coast line than the southern.

Storms that bring only light damage are often quite restricted in geographic extent. To determine the likelihood of a particular state with a coast line of a certain finite extent to receive appreciable damage, it is assumed that the less significant and more restricted light intensity storms should be disregarded. Assuming that storms bringing moderate and severe damage are sufficiently large to result in some damage to the whole coastal margin of the state in which damage is listed, it is possible to obtain a rough estimate, by state, of the recurrence interval for damaging storms. In the right-hand column of table 3-4, the number of storms resulting in only light damage to the coast has been removed from the total in each state, and the storm frequency is given as the number of years between storms resulting in moderate to severe damage.

The figures for frequency of damaging storms vary from one every 10 months (0.8 year) for Massachusetts to one every 3.1 years for Georgia and Delaware. The recurrence interval given for the entire Massachusetts coast is undoubtedly shorter than is really experienced along any particular coastal reach. This is because the coast is so oriented that it presents two distinct areas for coastal damage. The south-facing shore from Buzzards Bay to Chatham on Cape Cod is exposed to all winds from southeast to southwest. At the same time such winds result in generally offshore movement of water along the coast from Orleans on the northern side of Cape Cod to the New Hampshire border. Storms that affect the shore north and south of Boston and the north shore of Cape Cod have winds from the north and east. These might bring relatively little damage to the south shore of Cape Cod and Buzzards Bay. Thus, the orientation of the shore line has made part of the Massachusetts coast particularly susceptible to damage from storms with southerly winds and a different part of the coast susceptible to storms with northeasterly winds. Actually, the chance of coastal damage in Massachusetts is probably not much greater than in Rhode Island or New Hampshire. Separating the storm figures for Massachusetts into those affecting the southward-facing shore and those affecting the eastward-facing shore, the values of recurrence interval must approximate closely the figures of 1.5 years for Rhode Island and 1.7 years for New Hampshire. The low value of storm recurrence for North Carolina may similarly be influenced by the particular exposure of the coast line.

Information on the occurrence of damaging coastal storms can also be obtained from a study of the records from the tide-gaging stations that have been established along the coast. Records of height of the tides during each of the storms that occurred during the period 1952-1962 have been collected from the Coast and Geodetic Survey. The data at 29 gaging stations have been summed in table 3-5 showing the relation between intensity of damage and averages of the highest tide recorded during each storm. In this case, the damage estimates have been divided into five different classes -- very light, light, moderate, moderate to heavy, and heavy. The results show a reasonable relation between

Table 3-5

Average of Maximum Tides Above Mean High Water, by Damage Classes, 1952-1962

Gaging Station	Very Light		Light		Moderate		Moderate-Heavy		Heavy	
	No. Storms	Avg. Tide	No. Storms	Avg. Tide	No. Storms	Avg. Tide	No. Storms	Avg. Tide	No. Storms	Avg. Tide
Eastport	34	1.89	5	0.60	6	2.62	2	0.20	2	2.35
Bar Harbor	37	1.42	7	1.24	8	2.15	2	1.05	3	1.27
Portland	34	1.86	11	2.16	8	1.78	2	1.65	4	3.63
Portsmouth	25	1.75	6	2.08	6	2.10	2	2.60	3	2.97
Boston	37	1.55	9	1.90	9	2.00	5	2.86	4	3.58
Woods Hole	33	1.36	15	1.81	9	1.77	6	2.57	2	5.10
Providence	28	1.28	13	1.97	4	1.53	4	3.28	0	
Newport	38	1.38	14	1.87	5	1.90	4	2.80	1	7.40
New London	37	1.46	14	1.70	8	2.51	3	3.37	1	7.10
Montauk	53	1.55	4	2.18	3	2.40	4	2.52	4	4.25
Willets Point	58	1.96	5	2.60	4	4.40	3	2.97	4	5.00
Battery	56	1.56	5	2.44	4	2.75	1	2.30	4	4.58
Sandy Hook	38	1.71	7	2.71	3	2.97	1	5.70	2	5.15
Atlantic City	44	1.75	6	3.52	4	2.58	0		3	3.80
Reedy Point	33	1.13	3	1.70	4	1.45	0		1	3.50
Breakwater Harbor	48	1.75	4	2.82	3	2.30	0		1	5.30
Baltimore	55	1.25	4	1.25	4	2.38	0		1	3.30
Annapolis	53	1.18	3	1.47	4	2.15	0		1	3.60
Solomons	55	1.08	3	1.50	4	1.72	0		1	3.30
Hanpton Roads	21	1.54	5	2.32	0		3	3.93	4	2.68
Portsmouth	22	1.64	5	2.72	0		3	4.23	4	3.52
Little Creek	14	1.46	5	2.40	0		3	3.30	1	1.70
Morehead City	10	0.90	9	1.25	3	1.47	1	3.00	4	3.62
Wilmington	16	1.01	7	0.84	4	1.28	2	1.55	2	2.55
Charleston	22	1.73	2	2.15	2	1.90	0		1	3.40
Savannah River	8	1.99	1	2.70	3	0.90	0		0	
Fernandina	7	1.57	2	2.60	1	1.80	2	2.40	0	
Mayport	7	1.27	3	2.10	1	1.60	2	2.05	0	
Miami	1	0.80	2	1.45	1	0.70	3	1.63	0	
Average		1.48		2.00		2.04		2.66		3.79

height of the tide and damage category when the figures for all stations are averaged together although the relationship at individual stations varies markedly. The results from single stations, of course, are strongly influenced by the number of storms that have occurred at the station, the assignment of damage categories, the exposure of the gage itself, and surrounding environmental factors.

From table 3-5 it can be seen that on the average with observed tides 2 feet above mean high water light to moderate damage was experienced. The damage increased to moderate to heavy as the tide exceeded 2.6 feet above mean high water. Heavy damage was generally experienced with tides more than 3.8 feet above mean high water. The individual variation among stations still deserves special study in order to determine the influence of topography and exposure on potential damage.

The data in table 3-5 refer only to the tides that occurred during periods when there were reports of storms in at least one of the publications reviewed during the course of the study. A second method of looking at the data of high tides would be to obtain tide records for all tides above certain minimum values to see how often such tides occurred regardless of whether they resulted in damage. Since table 3-5 showed that tides 2 feet above mean high water resulted on the average in light damage, the tide records from the Coast and Geodetic Survey were rechecked to determine the number of times tides had exceeded 2 feet, 3 feet, and 4 feet above mean high water. The results for twelve selected stations along the coast are given in table 3-6. At the same time, the figures

Table 3-6

Number of Occurrences of Selected High Tidal Values

	Tides Above Mean High Water				Number of storms causing
	2.0-2.9 ft	3.0-3.9 ft	4.0+ft	Total	some damage
Portland	115	29	1	145	59
Boston	93	20	1	114	64
Newport	29	3	1	33	62
Montauk	29	7	2	38	68
Sandy Hook	44	8	4	56	51
Atlantic City	65	5	1	71	57
Breakwater Harbor	46	8	1	55	56
Hampton Roads	17	4	1	22	33
Portsmouth	28	4	4	36	34
Wilmington	4	0	1	5	31
Charleston	69	3	0	72	27
Mayport	12	0	0	12	13

from table 3-5 giving the total number of storms causing some reported damage (including very light) are also included in the right-hand column for comparison purposes. The discrepancies between the reported number of tides over 2 feet above mean high water and the reported number of storms causing damage are most revealing in indicating something of the difficulty in using tide records directly in assessing storm damage. In Portland, Maine, tides were more than 2 feet above mean high water 145 times during the eleven-year period 1952-1962 yet only 59 periods of any type of storm damage were reported. At Newport, Rhode Island, however, the tide exceeded 2 feet above mean high water only 33 times yet damaging storms occurred 62 times. Damage will occur with quite different heights of tide at different places along the coast. The relationship can vary greatly even along relatively uniform coastal reaches. Consider the great variation in the results from Wilmington, North Carolina, and Charleston, South Carolina, for example. Tides 2 to 3 feet above mean high water at Charleston hardly ever result in damage while tides considerably less than 2 feet above mean high water can cause reported damage at Wilmington. While these differences are clearly related to exposure of the gage and environmental factors in its vicinity, the individual or local nature of damage problems and the great variability from place to place is sometimes overlooked in an effort to draw general conclusions for long reaches of the coast.

Lateral Extent of Storm Damage

The damage history of storms may also be considered from a different point of view. While figures indicating the damage frequency at a point along the coast give some idea of the relative hazard along different reaches of the coast, they give no indication of the lateral extent of coast that might suffer damage from a single meteorological event. If one could predict the frequency with which coastal storms damage various lengths of coast line, such information, together with estimates of damage levels, would suggest the magnitude of the total damage risk from a national rather than a local point of view. An indication of the probabilities to be attached to storms damaging various lengths of coast line would suggest how often to expect total damages of various amounts and the geographic extent of such damage. This information might be helpful in planning of coastal disaster programs and estimating over-all levels of insurance risk that would be required for a national insurance program.

The length of coast line affected by a particular storm will, of course, depend largely on the intensity and size of the storm, its track, and speed of movement. A large storm of moderate intensity moving slowly up the coast can generate destructive storm surges and seas persisting for several successive high tides. Such storms will often affect 400 or more miles of coast line. A very slowly moving storm such as that of March 1962 may be of only moderately great intensity and yet prove extremely destructive simply because of its persistence and extensive area of wave generation.

Using the reports of damage that were available for each of the storms during the well-documented period from 1952 to 1962, supplemented by the records from the tide gaging stations, it has been possible to prepare maps of the lateral extent of damage from each storm. The damage was separated into only two classes, light and moderate to severe, because of the lack of detail in the data. Table 3-7 gives a summary of the average lateral extent in nautical miles of damage along the coast by each of the eight types of storms listed previously. The high value of lateral extent for type 5 storms is undoubtedly related to the fact that only three type 5 storms occurred during this period and they each covered a great

Table 3-7

Lateral Extent of Damage by Storm Types 1952-1962
(in nautical miles)

Type	Extent of Damage: Light (naut. mi.)	Extent of Damage: Moderate to Severe (naut. mi.)	Total Extent (naut. mi.)	No. of Storms
1	175	86	261	27
2	192	110	302	9
3	197	106	303	15
4	195	23	218	11
5	308	83	391	3
6	154	21	175	11
7	262	-	262	4
8	25	-	25	1

horizontal extent. It is possible that this figure would be reduced with the inclusion of additional storms of this type. The tabulation shows very little real difference in the lateral extent of damage from type 1, 2, 3, 4, and 5 storms. Type 6 and 8 storms are apparently much smaller in horizontal extent. Type 7 storms should influence a fairly short coastal area although the four type 7 storms that occurred between 1952 and 1962 were fairly extensive.

It is interesting to note that type 2 and 3 storms, cyclones forming over the southeastern coastal area or on cold fronts that have moved well off the southeast coast, seemed to damage a larger extent of coast line than did hurricanes. This was especially true in the southern section of the coast although again, the small number of such storms might bias the results. The results are probably influenced by the nature and orientation of the coast line in relation to the favored paths of movement of the various storm types.

At the present time only tentative predictions about the lateral extent of future coastal storms are possible. Predictions, in the absence of complete knowledge of the physical processes involved and with the important assumption of no climatic change, must be based on the record to date. However, this record is a shaky basis for prediction not only because the data themselves are in need of refinement, but also because it shows the over-all vulnerability of the coast to be increasing with time. Only if the pattern of coastal occupancy is frozen at the present level would it be in any way realistic to attempt to look into the future. With this proviso, we can now examine the record of the past 30 years in order to assess the future.

Maps of extent of coastal damage were prepared for each of the 121 damaging storms that occurred during the 30 years 1935 through 1964. For this analysis, the lateral extent of damage was defined as the not necessarily continuous length of coast line, in nautical miles, for which any significant water damage (any damage but that classed very light) was reported for a single storm event.

Table 3-8 shows the lateral extent of significant damage produced by the 121 storms by year. It is seen that 81 percent of the storms damaged less than 400 nautical miles and that 97 percent of the storms damaged less than 700 nautical miles of coast. Only 4 storms during the period significantly affected more than 700 miles of coast.

The over-all trend previously noticed (figure 3-1) toward a higher incidence of damaging storms has been reflected in an increase in the frequency of storms in all classes of lateral extent. In figure 3-9, the lateral extent of damage per storm has been plotted against the logarithm of the average number of storms per year having that extent. For the 30-year period, this plot seems to be fairly well represented by a straight line on semilogarithmic paper, implying that frequency per year is a negative exponential function of damage extent. Because there are so few very extensive storms, the quality of the fit deteriorates for very extensive storms.

One might be inclined to use the record to predict expected frequencies, assuming that the past may be relied upon as a satisfactory guide to the future. That there has been a change during the period of study is clear in figure 3-9 where the history of the latter 15 years is compared to the whole period. The same general relationship between frequency and damage extent appears to hold for the more recent years, except that the incidence per year of storms in almost all classes has been higher than for the whole 30 years. Consequently, prediction would require assuming the pattern and level of coastal development to be frozen at the present state and should be based on the most recent storm record. Under these conditions, there would be some reason to believe that a storm damaging about 600 nautical miles of coast would be expected to occur on the average every 1/.3 or 3.3 years, and a storm damaging about 1300 miles (such as the March 1962 storm) might be expected about once in 1/.035 or 29 years.[1]

A better and more useful prediction might be based on the theory of extreme values. The statistical theory of extreme values applies to the frequency distribution of the largest observation per sample of N primary samples, each of which primary sample contains $\underline{n}$ observations of unspecified number, but assumed to be large and equal.

In the present case, this stipulation of $\underline{n}$ large and equal is not applicable since we are actually dealing with relatively unlikely events; i.e., damaging storms per year that have occurred only around 0 to 11 times per year. We are trying to predict the magnitude of damage extent of these events. The applicability of the theory in such a case can only be tentative and will depend on the goodness of the fit of the data. There is some reason to suppose that a double exponential distribution will adequately describe the extreme values of the data since the basic distribution does appear to be exponential.

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[1] The east coast of the United States can be considered to be approximately 1600 nautical miles in extent if bays and other minor indentations are disregarded.

Table 3-8

Distribution of Lateral Extent of Storm Damage by Years (1935-1964)

	Lateral Extent in Nautical Miles													
	1-100	101-200	201-300	301-400	401-500	501-600	601-700	701-800	801-900	901-1000	1001-1100	1101-1200	1201-1300	Number Storms
1964	6	1	1	1										9
1963	3	2	1		1									7
1962	2	3		3	1					1			1	11
1961	2	1	1	1		1								6
1960	3	2		1	1							1		8
1959	2		3			1								6
1958	2	1	1	2	3		1							10
1957	3	1		1										5
1956	1	1	1	1		2								6
1955			3	1										4
1954		1			2		1							4
1953		2	1	1		1								5
1952		1		1										2
1951	2													2
1950	2	1		2		1								6
1949	1						1							2
1948		2												2
1947	3	4												7
1946	2	1	1											4
1945	1						1							2
1944			1				1	1						3
1943	1		1											2
1942														0
1941														0
1940	1													1
1939														0
1938				1										1
1937	1													1
1936			1											1
1935	4													4
Totals	42	24	16	16	8	6	5	1	0	1	0	1	1	121

RELATION BETWEEN AVERAGE NUMBER OF STORMS PER YEAR AND THEIR LATERAL EXTENT OF DAMAGE FOR TWO TIME PERIODS

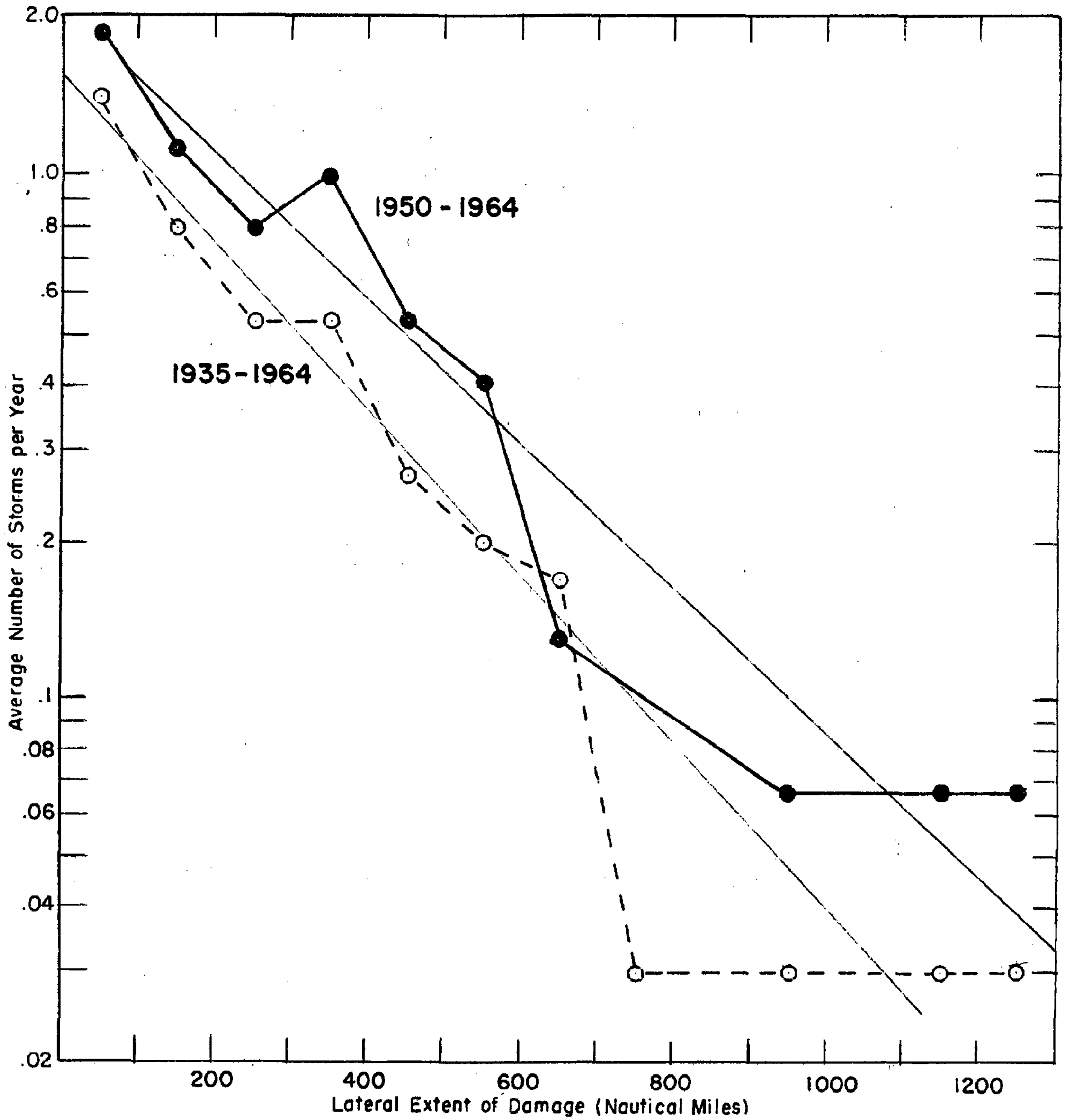


Figure 3-9

The method described by Gumbel was used to fit the extreme value curves in figure 3-10 to the most extensive damaging storms per year for the two 15-year periods, 1935-49 and 1950-64. Comparison of the two plots clearly shows an increase in the extent of the most extensive storms. During the former 15-year period, the probability of getting a storm during a year that damaged 600 or more nautical miles of coast was about .13; while during the latter period, the probability for such a storm had increased to about .42. Relying on the record of the recent 15 years, then the return period implied for a storm of <u>at least</u> 600 miles extent is 1/.42 or about 2.4 years and for a storm damaging at least 1300 miles of coast, 1/.05 or 20 years.

Causes for Increasing Storm Damage Frequency

X

The foregoing analysis of storms along the east coast of the United States has shown a great increase in the number of such storms in recent years. The cause of this increase needs real study. Is the present high number of damaging storms the result of better reporting? Is it the result of a real climatic change? Or is the increase the consequence of more intensive development of the coastal margin so that storms that formally would have been considered benign now result in damage?

There is some reason to believe that improved reporting is not the major cause of the increase in reported damage. If there were a marked improvement in reporting, an increase in the number of reported storms causing comparatively insignificant damage would be expected. Table 3-9 shows no such increase in the number of insignificant

Table 3-9

Number of Cyclonic Centers and Damaging Storms
During Two Different Periods of Time

	Number of closed lows within 100 mi.	Significant to heavy damage	Significant damage	Insignificant damage
1949	68	0	2	0
1950	56	2	3	2
1951	65	0	2	4
1952	66	0	2	3
1953	61	2	3	0
Total	316	4	12	9
1960	62	2	6	1
1961	57	3	2	2
1962	64	4	7	1
1963	61	2	5	2
1964	67	1	7	2
Total	311	12	27	8

damage storms. Of course, it could be argued that improved reporting may have resulted in the "promoting" of reported storms. That is, storms now assigned significant damage might previously have been listed inaccurately as insignificant as a result of poor reporting. Storms now called insignificant might not even have been reported in earlier years. However, there is no evidence that this has occurred.

In order to see whether there has been a climatic change in the number of storm centers, daily weather maps for two 5-year periods (1949-53 and 1960-64) were examined. There were reports of 25 damaging storms in the earlier period and 47 in the more recent period.

The appearance on the weather map of a closed low within 100 miles of the east coast (either inland or seaward) was accepted as a criterion for a possible coastal storm. All such lows for which there was no report of damage were considered non-damaging storms. Both the midnight and noon maps were examined for each day of the two 5-year periods (except for ten days when the maps were missing). If two or more closed lows appeared within 100 miles of the coast on the same map, and if they appeared to be part of a single meteorological disturbance, they were counted as only one storm. If a particular low appeared on more than one map, it was, of course, counted only once.

The total number of damaging storms for each year is compared with the number of closed lows in table 3-9. Despite the increase in number of damaging storms in recent years, the total number of closed lows moving within 100 miles of the coast has remained essentially the same. Consequently, if the increase in damaging storms is to have a climatological origin, there must have been a change in some other statistic such as storm intensity or storm track.

To test the possibility that low pressure systems tended to be deeper during recent years, the central pressures of all the closed lows occurring within 100 miles of the coast during the period 1952 to 1962 which produced significant damage were studied. The average minimum central pressures for these storms is given in table 3-10. The table shows that:

1) The average minimum central pressure of heavy damage storms is in general lower than that of significant damage storms.
   This seems to indicate that there is a relationship between central pressure and damage.

2) The number of damaging extratropical storms has increased, a fact previously established.

3) Central pressures of damaging extratropical storms tend to be lower in more recent years. This is evident for both significant damage and heavy damage storms. In fact, the average minimum central pressure of all damaging extratropical storms occurring during the years 1958-1962

CUMULATIVE FREQUENCY OF LATERAL EXTENT OF LARGEST STORM PER YEAR. 1935-'49 & 1950-'64

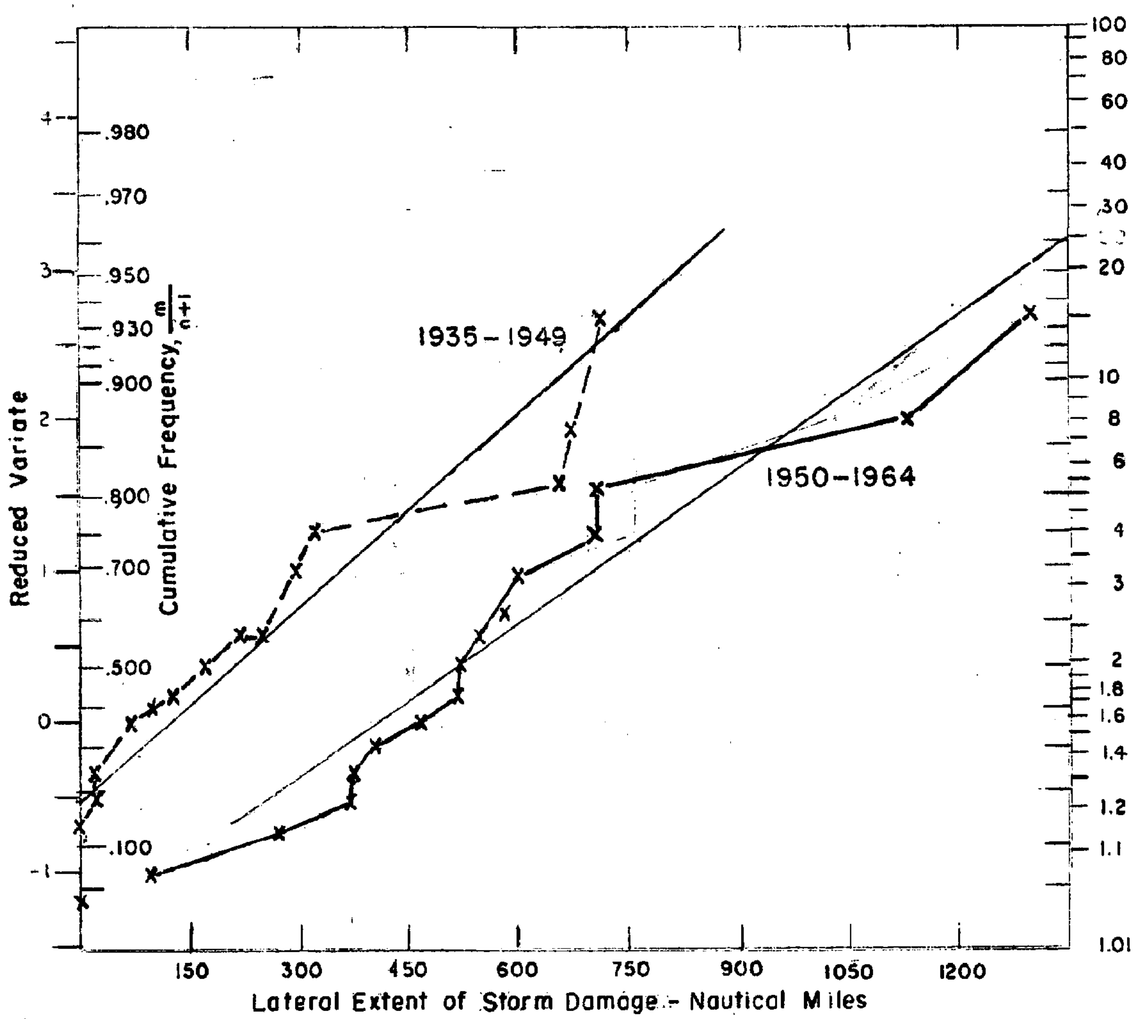


Figure 3-10

is 11.6 mb lower than the average minimum central pressure of storms for the years 1952-1957. Students t test with 45 degrees of freedom shows this difference to be significant at the 1 percent level.

Table 3-10

Average Central Pressures of Damaging Storms by Years, 1952-1962
Tropical and Extratropical Storms
(pressure in mb)

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Extratrop.-sig. damage	1	2	1	1	4	5	9	5	6	4	9
Avg. min. central press.	1011	994	1005	1000	996	1004	989	982	990	988	993
Extratrop.-heavy damage	0	2	0	0	3	1	2	2	1	1	3
Avg. min. central press.		994			991	996	982	984	980	984	985
Tropical-sig. damage	1	3	3	3	2	0	1	1	2	2	2
Avg. min. central press.	1005	975	980	976	1002		984	992	986	988	994
Tropical-heavy damage	0	0	3	3	2	0	1	1	1	2	1
Avg. min. central press.			980	976	1002		984	992	976	988	996

Note: Data are averages of the lowest pressure found on the synoptic map for each storm.

Does this difference in minimum central pressure indicate a climatic trend or change or can it be explained in any other way? If, of course, there has been no climatological change, then the increase in number of damaging storms must have resulted from the increasing vulnerability of the coast itself. Several different lines of evidence have been used to study the possibility of climatic change or trend.

The frequency of high tides by years at selected east coast points is shown in table 3-11. The table shows that there has been a small increase in the average maximum high tide at five of the seven stations during the eleven years. Since the change has been rather small, it would not seem to be related to the increase in storm damage found during the period.

However, totaling the number of excessively high tides shows that there has been a marked increase in the frequency of very high tides. For example, at Portland there was only one tide over 3.5 feet above MHW from 1952 to 1956, but there were seven in the 1957-1962 period. Montauk had three tides over 3.0 feet above MHW during the early period and six between 1957 and 1962. Atlantic City had one tide over 3.5 feet above MHW in the first period and three in the second. Thus, the evidence from the tidal record suggests an increase in excessively high tides that appears to be correlated with an increase in the strength of the damaging low pressure systems.

Table 3-11

Frequency of Maximum High Tide above Mean High Water by Year

Tide above MHW (feet)	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Portland, Maine											
2.0-2.4	10	9	5	3	6	4	7	5	7	4	6
2.5-2.9	2	3	4	5	0	7	8	3	5	7	5
3.0-3.4	2	3	1	4	2	0	1	2	3	2	3
3.5-	0	0	1	0	0	0	2	1	1	3	0
Total	14	15	11	12	8	11	18	11	16	16	14
		Avg. ht. 2.54						Avg. ht. 2.65			
Boston, Massachusetts											
2.0-2.4	4	5	5	5	7	5	7	6	6	10	5
2.5-2.9	2	2	2	4	3	2	5	2	4	0	2
3.0-3.4	2	2	1	1	0	0	3	1	2	3	1
3.5-	0	0	0	0	1	0	1	1	0	1	1
Total	8	9	8	10	11	7	16	10	12	14	9
		Avg. ht. 2.50						Avg. ht. 2.55			
Montauk, Long Island											
1.5-1.9	5	2	4	4	5	3	6	0	4	4	3
2.0-2.4	1	1	1	0	2	1	7	1	5	3	1
2.5-2.9	0	0	0	1	0	0	0	1	0	3	1
3.0-	0	1	1	0	1	0	2	0	2	1	1
Total	6	4	6	5	8	4	15	2	11	11	6
		Avg. ht. 2.59						Avg. ht. 2.49			
Atlantic City, New Jersey											
2.0-2.4	5	2	5	1	6	7	6	3	6	4	1
2.5-2.9	1	1	1	3	3	0	2	1	1	2	3
3.0-3.4	0	0	0	0	0	0	0	0	0	1	0
3.5-	0	1	0	0	0	0	0	0	1	1	1
Total	6	4	6	4	9	7	8	4	8	8	5
		Avg. ht. 2.41						Avg. ht. 2.45			
Portsmouth, Virginia											
2.5-2.9	2	3	5	2	4	1	3	2	3	1	2
3.0-	0	0	0	0	2	1	1	0	1	1	2
Total	2	3	5	2	6	2	4	2	4	2	4
		Avg. ht. 2.58						Avg. ht. 2.73			
Charleston, South Carolina											
2.0-2.4	1	2	5	3	5	6	8	4	8	6	9
2.5-2.9	0	2	1	1	0	1	1	2	2	1	1
3.0-	0	0	0	0	0	0	0	1	1	0	1
Total	1	4	6	4	5	7	9	7	11	7	11
		Avg. ht. 2.30						Avg. ht. 2.34			
Mayport, Florida											
1.5-1.9	4	4	7	6	5	6	4	6	4	4	5
2.0-2.4	0	1	2	0	0	2	1	1	3	0	1
2.5-	0	1	0	0	0	0	0	0	0	0	0
Total	4	6	9	6	5	8	5	7	7	4	6
		Avg. ht. 2.32						Avg. ht. 2.20			

An increase in height of the tides or a decrease in the central pressure of damaging low pressure systems would seem to be a climatological trend unrelated to possible changes in coastal vulnerability. It is possible, of course, that something else besides just a deepening of central pressures is involved. The possibility of a shift in storm tracks or in the paths of movement of the low pressure systems must also be considered.

Previous studies have shown a greater increase in damaging storms in recent years along the northern portion of the coast. It is further recognized that low pressure areas at higher latitudes are more strongly developed and have lower central pressures than in lower latitudes. Thus, it might be possible to explain the deepening of the central pressures of damaging storms as well as the increase in the damage to the northern portion of the coast line by means of a northward shift in the locations of storm centers in more recent years. Figures 3-11 and 3-12 show the location of the minimum low pressure observed for each destructive storm for the two periods 1952-1957 and 1958-1962. Aside from the more than twofold increase in storm frequency, two other changes are obvious.

1. The marked increase in the number of damage producing centers that attain greatest intensity outside of the zone 100 miles east and west of the coast.

2. The marked increase in number of damaging storm centers reaching their greatest intensity north of 40°N.

This second point might indicate a northward shift in the location of the storm centers except that a count of storms both north and south of latitude 40°N (table 3-12) reveals no corresponding decrease in number of storms south of 40°N. If nothing more than a northward shift of low centers was involved, assuming no significant change in total numbers of lows affecting the coast (table 3-9), it would be expected that an increase in low pressure centers north of latitude 40°N should be almost balanced by a corresponding decrease in the number to the south of that latitude. This evidently has not occurred so that a mere shift in location of low pressure centers can be discarded.

Table 3-12

Changes in Number and Central Pressure of Lows
North and South of Latitude 40°N 1952-1962

	North of 40°N		South of 40°N	
	Number	Avg. Min. Pressure (mb)	Number	Avg. Min. Pressure (mb)
1952-1957	1	998	13	1001
1958-1962	17	987	16	992

Table 3-12 shows a 3 to 5 mb change in pressure between lows south of $40^{O}N$ and those north of $40^{O}N$. This change is evidently related to the stronger development of cyclones at higher latitudes. The significant trend is the change in pressure of all lows between the 1952-57 period and the 1958-62 period. There was a deepening of pressure of 9 mbs during this time in those lows south of $40^{O}N$ and of 11 mbs in those north of $40^{O}N$.

The results would seem to verify a change in intensity of low pressure areas without necessarily suggesting any change in storm tracks or locations of the damaging low pressure centers. Still no physical reason for this trend is readily apparent. And, of course, there is no indication that this apparent trend is the only thing responsible for the increase in damage along the coastal margin.

It is clear from the results expressed elsewhere in this report that there has been a rapid and, in most cases, unplanned and possibly even unsound, development of most coastal areas over the past ten or more years. This development has undoubtedly resulted in a weakening of the natural coastal defenses against storms, and of course, made possible the greatly increased dollar values of damage. Thus, these two aspects, the increase in number and strength of damaging low pressure areas and the weakening of coastal defenses, both will result in the same end -- an increase in damage frequency and amount. It is not yet possible to separate out the exact contribution of each but it appears that they have both played a part in our recent coastal damage experience. A great deal of further study of these aspects needs to be done in an effort to identify the real contribution of each.

Analysis of Damage Frequency

Thirty years of detailed recorded storm damage covering 1935-1964 have been analyzed to determine the frequency of damage to all points along the east coast of the United States. The coast line as defined here omits the interior shorelines of bays and estuaries, such as the Delaware, Chesapeake, and Cape Cod Bays, and Long Island Sound. The coast thus defined extends 1600 nautical miles from Eastport, Maine, to East Cape, Florida. The coast has been divided into sixty-four increments or reaches of 25 miles each.

Descriptions of the damage sustained along the coast were obtained and evaluated for severity for each 25-mile reach of the coast. Damage reports for interior coast lines of bays and sounds were averaged with those for the exterior coast lines. Damage to property judged from the reports to be due to flood or wave action and incidents of beach erosion were mapped for each storm. Information on the heights of abnormal tides along the coast were also used to judge the severity of each storm at various points along the coast. The tide information aided in determining the lateral extent and intensity of the storm damage. It was used as a supplement to and a check on the actual damage reports. By using both damage and tide information, it was possible to get some idea of the broad pattern of the potential for damage along the coast including uninhabited places and sites between points of definite reported damage. The resulting pattern is, therefore, a combination of actual damage to vulnerable points along the coast

LOCATION OF DAMAGING EXTRA-TROPICAL STORM CENTERS AT THE TIME OF MINIMUM CENTRAL PRESSURE

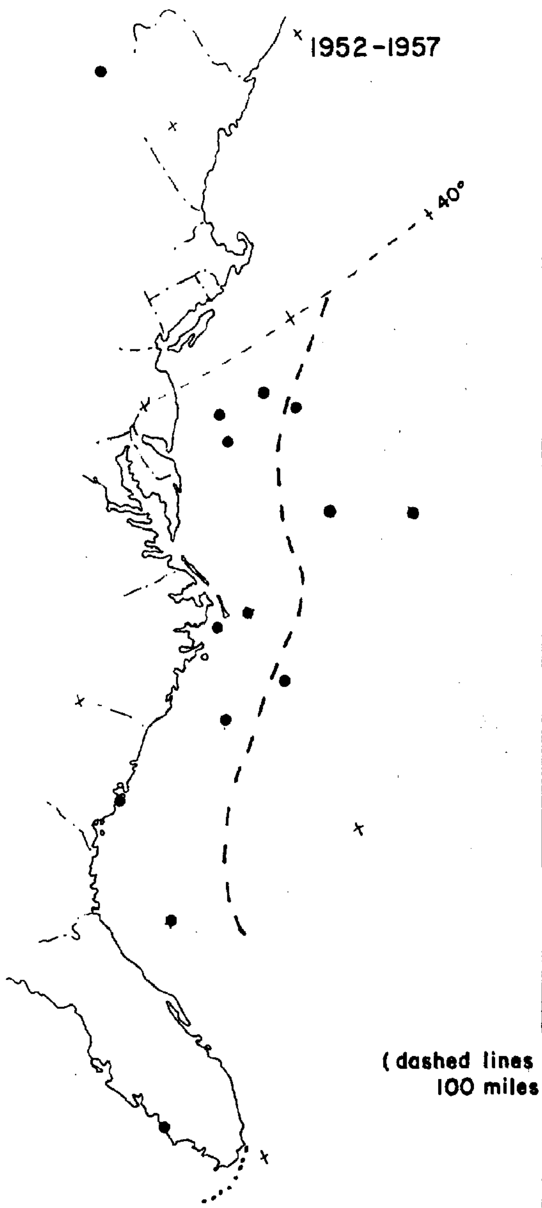


Figure 3-11

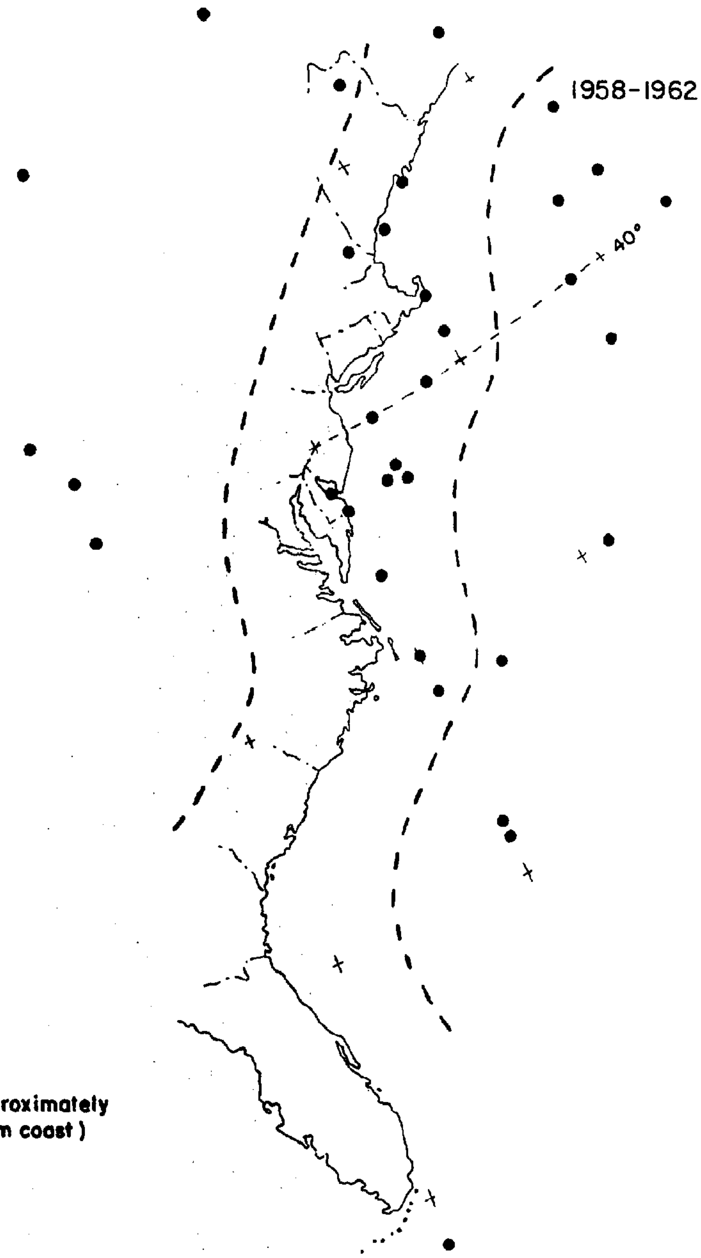


Figure 3-12

(dashed lines approximately 100 miles from coast) and a generalization of this damage frequency to nearby points that may or may not be vulnerable at future times depending on local circumstances. In this way, it was hoped to free the analysis from excessive reliance on detailed local topographic and human occupance factors, and thereby to obtain a measure of the board patterns of hazard along the coast.

There were some storms in which the damage reports indicated only inconsequential damage. In other cases, it was difficult to distinguish between major and inconsequential beach erosion. Therefore, the 121 damaging storms analyzed here include only those storms in which there was judged to be greater than minimal damage to real estate or natural coastal defenses somewhere along the coast. Intermediate points were sometimes considered to have been damaged when tides were as high as the tides known to be associated with damaging storms.

A map of the damage (actual and potential) produced by each storm was prepared for each of the 121 storms. From these maps the frequency of significant damage for each 25-mile reach of coast was determined.

The over-all frequency of damaging storms for the whole length of coast line has increased over the 30 years from about 1 per year to a current frequency of about 8 damaging storms per year. The frequency of damaging storms per 25-mile reach of coast line is shown in figures 3-13, 3-14, and 3-15 for the three decades 1935 through 1964. (The number of storms per segment has been rounded up to the nearest even number to simplify the results.)

Of the total of 121 damaging storms during the 30-year period, the number per decade increased from 12 during the years 1935-44 to 35 during 1946-54 and to 71 during the final ten years 1955-64. In each of the three decades, just under one-half of the storms seriously affected the vicinity of Cape Cod on the southern New England coast. It is clear from figures 3-14 and 3-15 that since 1945 the New York-New England coast has been significantly more subject to storm damage than has the remainder of the United States east coast lying to the south of New York City. During the just completed decade, for instance, there were an average of 22 damaging storms for each 25-mile segment of coast line between New York City and Eastport, Maine. By contrast, there were only an average of 8.3 storms bringing damage to each of the 25-mile segments south of New York. Within New England, storm damage was most frequent along the Rhode Island-Massachusetts coast line, where there were an average of 28 damaging storms per 25-mile segment between Provincetown, Massachusetts, and Groton, Connecticut. North of Provincetown, the number of damaging storms is only slightly lower.

Nowhere south of New York does the total number of damaging storms exceed the storm frequencies experienced in New England. And the average frequency, as noted above, is less than half that experienced in New England. Yet, within the southern coast (in this context, the whole coast south of New York) the region immediately north and south of Cape Hatteras, from Albemarle Sound to Cape Fear, not surprisingly, has been damaged more often than any other reach of the southern coast during the past ten years. It is interesting to note, however, that there has been a marked increase in the relative damage frequency along this reach of coast since 1955. This may reflect accelerated development. The number of structures in the Nags Head study site almost doubled in the decade 1953-1963.

There are two reaches of the coast south of New York where damage frequency during the past ten years has been notably lower than the average for the whole coast. These include an extensive reach of the New Jersey coast north of Atlantic City and the bight of coast from the vicinity of Charleston, South Carolina, to the vicinity of Palm Beach, Florida. During the decade 1945-54, however, this reach of coast line showed a greater relative frequency of damaging storms than was observed during the other two decades of the 30 years under study.

Maps were also prepared to show the frequency of heavy damage-producing storms for each of the three decades. Figures 3-16, 3-17, and 3-18 show the frequency of heavy damage for comparison with the frequency of all significant damage shown in figures 3-13, 3-14, and 3-15. Of the total 121 storms, 48 resulted in heavy damage somewhere along the coast.

Again, the whole New England coast is significantly prone to damage. During the last decade, each of the nineteen 25-mile segments between Eastport and New York City received an average of almost 6 heavy damage-producing storms during the ten years. To the south of New York, only in the Hatteras area, and the area near Norfolk, Virginia, is there found an equivalent frequency of heavy damage during the just past ten years.

Broad categories of relative storm hazard were assigned to individual segments of the coast line from the storm frequencies shown in these two sets of maps. In evaluating the relative hazard, it seemed appropriate to give more weight to storms producing heavy damage. This is necessary since the dollar value of damage is usually given in damage classes increasing by factors of ten. Consequently, the difference between moderate and heavy damage may correspond to dollar loss differences of several orders of magnitude. In order to make some allowance for this fact in assigning values of relative hazard, double weight has been given to heavy damaging storms.

Figures 3-19, 3-20, and 3-21 show the relative coastal storm hazard by 25-mile sections of coast line for the three decades. The relative hazard is simply the total number of damage occurrences per reach, with heavy damage occurrences being given double weight. (The actual, unrounded storm frequencies were used. Consequently, there may be a discrepancy of one storm between the hazard value and the sum of storm frequencies in figures 3-13 to 3-18.) The weighted damaging storm frequencies were broken down into four classes of hazard: 1-10 (light hazard), 11-20 (moderate hazard), 21-30 (considerable hazard) and 31-up (great hazard).

Figure 3-21 indicates relative hazard of coastal damage at the present time based on the history of the last ten years. The New England coast around Cape Cod is the only reach of coast that experiences great hazard. Two other regions, the balance of the New England coast line south to New York together with the Hatteras region from Albemarle

NUMBER OF STORMS PRODUCING SIGNIFICANT REPORTED DAMAGE ALONG INDICATED REACH OF COASTLINE

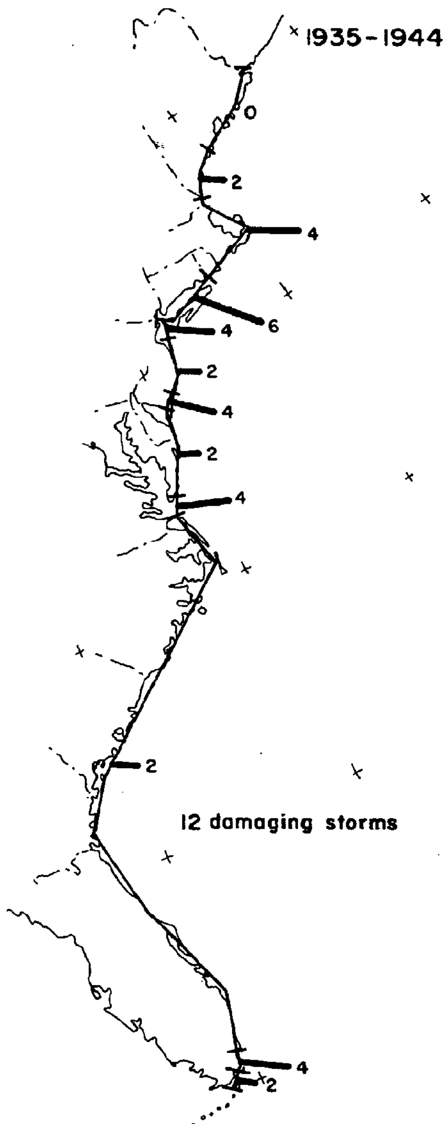


Figure 3 - 13

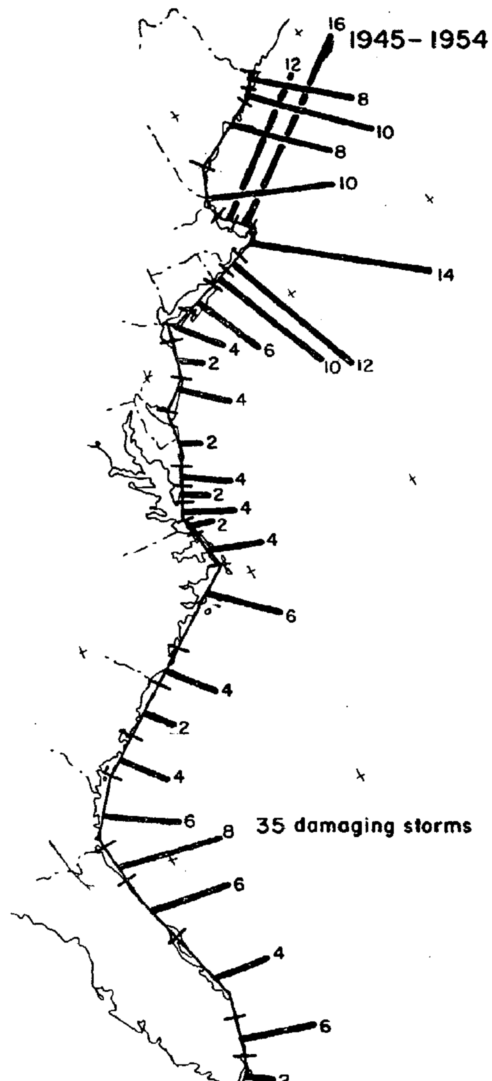
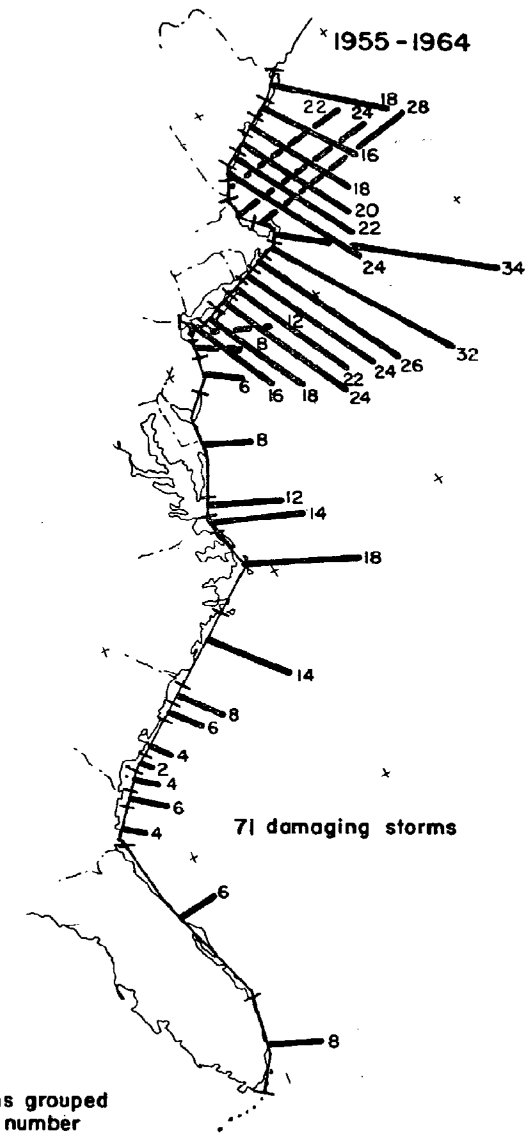


Figure 3 - 14



Number of storms grouped to nearest even number

Figure 3 - 15

NUMBER OF STORMS PRODUCING HEAVY DAMAGE
ALONG INDICATED REACH OF COASTLINE

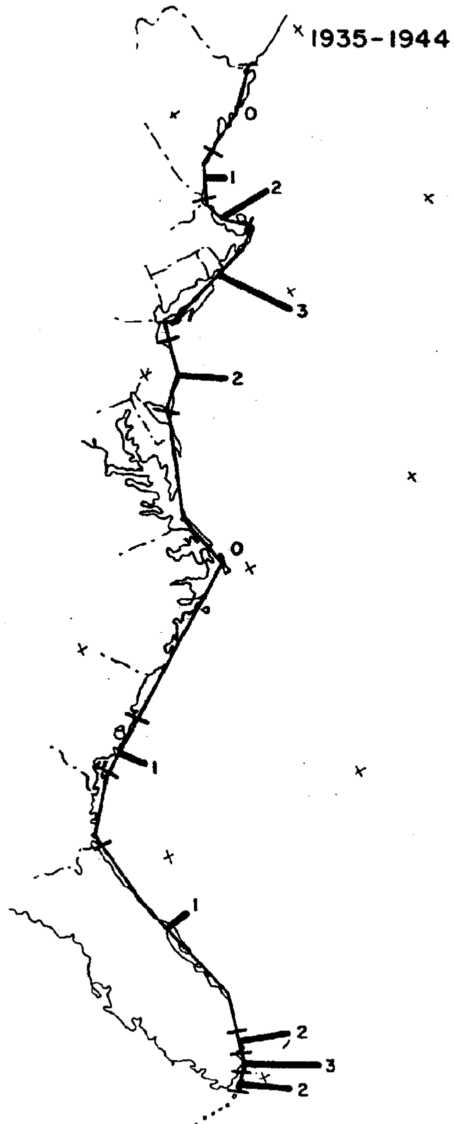


Figure 3 - 16

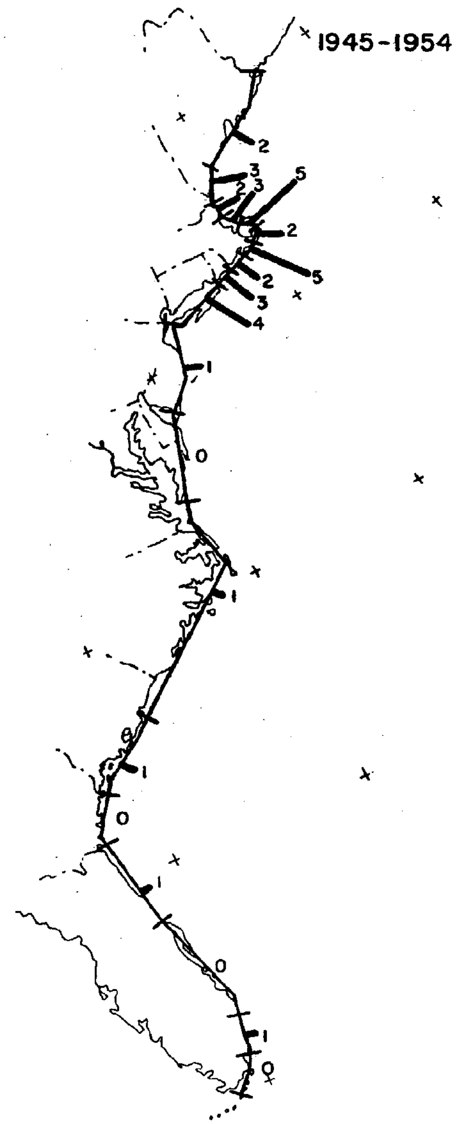


Figure 3 - 17

Figure 3 - 18

REGIONS OF RELATIVE COASTAL STORM DAMAGE HAZARD

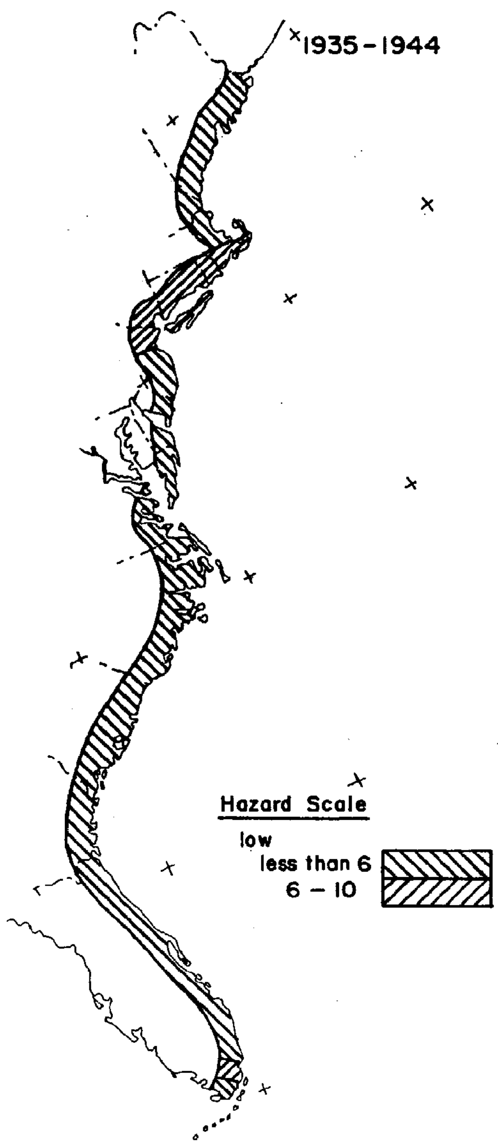


Figure 3 - 19

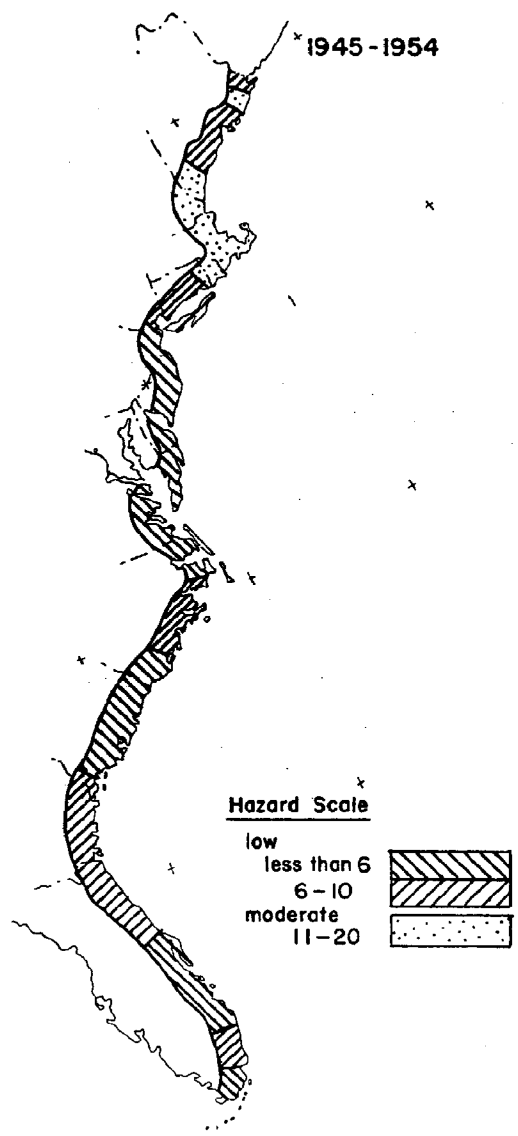


Figure 3 - 20

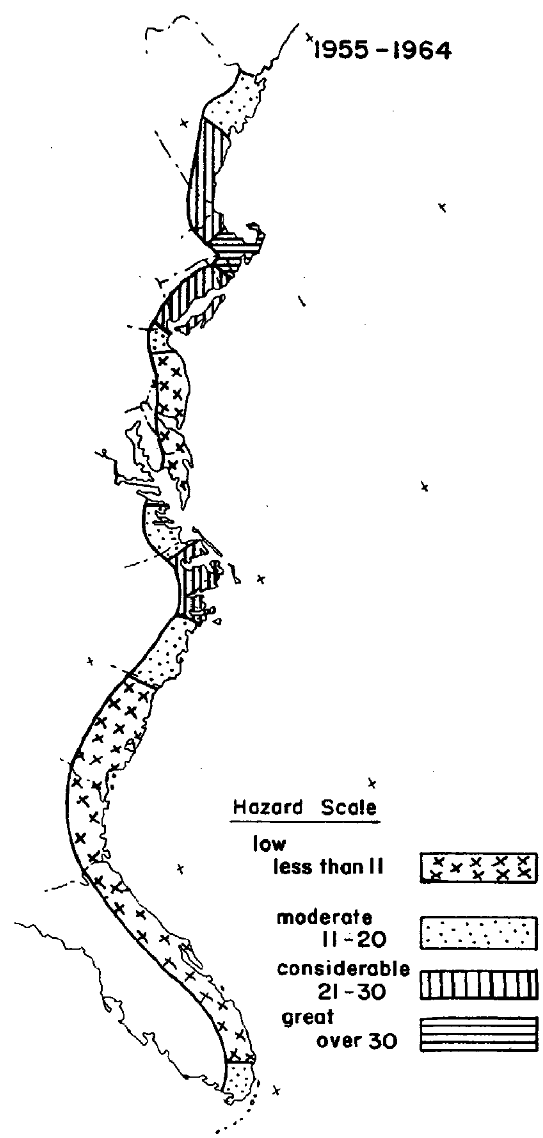


Figure 3 - 21

Sound to Morehead City are found to be considerably hazardous. The coasts of New Jersey, the Delaware peninsula, South Carolina, Georgia, and Florida are all found to experience only low hazard. Of course, it is to be remembered that these definitions have been made in terms of frequency of damage and occasional highly damaging events occur on these low hazard coasts. The high damage caused by the occasional severe storms along a low hazard coast may, of course, be more a consequence of the pattern of coastal development than the severity of the infrequent attacks by storms.

Conclusions

The foregoing study of coastal climatology has shown something of the great increase in storm hazard that has occurred in recent years. A review of possible reasons for this increase suggests that man as well as nature have been responsible. While the likelihood of a devastating storm like that of March 1962 may be only one in 20 to 30 years, the more frequent storms of restricted extent result in an over-all frequency of damage that is much greater. Continued action by man in developing the coastal margin can only increase this damage potential unless great care is exercised in the future development of the coast.

While the present study should now be refined to permit determination of the likelihood of damage area by area, the broad scale picture is clear. The southern New England coastal margin is particularly vulnerable to coastal storm damage. Further developments here should be carefully considered. Many parts of the New Jersey and Maryland-Delaware coasts are more favorably situated but of course here, use of the low lying offshore bars invites damage. The exposed Hatteras region is an area subject to great damage potential as is the southern Florida area. The other areas while suffering damage from time to time seem to be much more favorably situated although along no part of the coast should unrestricted development be permitted. Coastal storms occur too frequently to permit the increased occupancy of the coast without adequate warning or understanding on the part of all users concerning the potentials for damage. It would seem that only through education of the coastal inhabitants and builders to the damage potential from coastal storms can any permanent and effective solution to this serious problem be achieved.

CHAPTER IV

HUMAN ADJUSTMENT TO COASTAL FLOODING

Over the long span of settlement on the outer shore, many adjustments to the hazards of coastal flooding have evolved. These range from construction of massive engineering works designed to keep the sea away to the passive acceptance of losses when storms occur. Between these extremes are many alternate strategies designed to minimize danger to life and damage to property, to keep water out of structures, to keep structures out of floodable areas, and to bolster natural defenses against coastal floods.

This chapter explores the prevalence of these adjustments considering their extent, diversity, and efficiency in reducing damage. For this we have drawn heavily upon special surveys of damage from tidal flooding, or on studies of the extent of coastal engineering structures, zoning laws, and interviews with nearly 400 commercial and residential users of the shore.

Loss Bearing

The most common adjustment to coastal flood hazard is simply to suffer damages when they occur. Estimates of the extent and value of such damages are, however, extremely difficult to make. Damage stems from the action of both wind and water, and in general, wind damage is insurable and water-borne damages are not. Data on flood damages are collected consistently only by the Weather Bureau and the Corps of Engineers; the former by written questionnaire; the latter by survey. Seldom do their estimates agree. Some coastal damages enter into these general estimates of flooding, others into estimates of storm or wind damage, and estimates of beach erosion losses are usually prepared only in connection with specific studies. No agency collects data specifically on losses from tidal flooding.

Therefore, to provide an order of magnitude estimate, data on losses from tidal inundation have been brought together from the hurricane studies prepared under the authorization of P. L. 71 by the Corps of Engineers.[1] The studies available to date cover about one-third of the 1300 miles of study shore, and tend to concentrate on areas of high damage. They do not provide an adequate sampling of the whole shore. Within these studies, two types of damage estimates are found: average annual damages calculated for the relatively small areas where projects were recommended or considered, and estimates of the recurrence of a single large storm, such as the 1938 hurricane, for more extensive areas.

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[1] Public Law 71, 84th Congress, 1st Session, authorized the Corps of Engineers "to cause an examination and survey to be made of the eastern and southern seaboard of the United States with respect to hurricanes, with particular reference to areas where severe damages have occurred."

Thus for 215 miles of the study area (16 percent) recurring average annual damages are estimated by the Corps of Engineers at about $10,000,000 and for 441 miles of the study area (34 percent) damages exceeding $385,000,000 are estimated to arise from the recurrence of a single catastrophic event. This might be further compared with the losses estimated to have occurred from the March 6-9, 1962 storm of $192,000,000.

A somewhat different measure of the magnitude of loss bearing is derived from the interview data. Using a qualitative measure, damage was classified into light, medium, and heavy. Light damage, reported by 15 percent of the 371 respondents, was damage mainly to lawns and grounds. Medium damage, reported by 16 percent, includes damage by inundation mainly to contents of buildings. Heavy damage suffered by 22 percent of respondents involved major structural damage as well. Thus well over half of the respondents had suffered some sort of water damage in their occupance of the shore.

Not subject to classification or evaluation is the loss of life from coastal storms. Fortunately the cases reported occurring on shore are few and far between. Dangerous situations do exist; the large causeway at the Pt. Judith site is evidence of the recognition of the danger especially on isolated barrier bars. Loss of life has been reduced by the widespread implementation of warning procedures and emergency adjustments, the next set of adjustments to be considered in this review.

Warnings and Emergency Actions

The sensitivity of coastal dwellers, recreationists, and commercial interests to weather has always been high. Marine interests actively seek accurate weather forecasts and the chain of warning, communication, and action related to tidal flooding is built, in part, on the existing network of coastal warning facilities. This chain shown in figure 4-1, involves the assemblage of three types of information required for a tidal flood warning. Meteorological forecasts of atmospheric systems whose winds provide the major motive force for onshore water movements, are combined with tidal predictions and topographic data on the shore and foreshore. At least four major agencies are involved, but primary responsibility rests with the Weather Bureau.

A specific warning then enters the warning network for dissemination to both shore and marine users. In the study area the warnings are issued from 10 stations along the study shore.[1] The warnings reflect their maritime history and are based on the flag display system for small craft in which wind speed is the major variable. For seaward display, warnings go to communications media, the Coast Guard, marinas, and yacht clubs. For landward dissemination, they are sent to police, civic officials, civilian defense organizations, and through various arrangements to the business and agricultural community. Table 4-1 presents a typical notification list used at one of the stations along the study shore.

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[1] Memorandum dated April 22, 1963, N. A. Matson, Chief, Emergency Warning Section, U.S. Weather Bureau.

Table 4-1

Sample Warning Network, by Type of Warning

Type of Warning	Cumulative Network
Small Craft (Winds $\leq$ 33 knots)	Coast Guard Stations Life Guard Stations Marinas, Yacht Clubs Other Flag Display Stations Radio Stations
Gale, Whole Gale (Winds 34-63 knots)	Shore Police Departments Utilities Airfields Newspapers Piers
Hurricane (Winds $\geq$ 64 knots)	Civil Defense Red Cross School systems Inland Police Departments Chamber of Commerce list Agricultural Network
Tidal Flood	Included where appropriate with above storm warnings

The prediction of tidal floods. Tidal flood warnings are but one of the variants of storm warnings in the network, but one that places critical pressure on the predictive capacity of the forecaster. This problem has been summarized well by the Weather Bureau at a Congressional hearing.

> "The problem of predicting inundation, erosive wave action, and damaging wind along the coast is a complex one. It is basically a meteorological problem involving the development and movement of atmospheric storms. However, the problem embraces a spectrum of related oceanographic factors, including the process of interaction between ocean and air which generates large waves and causes storm surge, the latter augmenting the normal astronomical tides. The height and frequency of wave crests generated by storm winds depends both upon the strength and duration of strong winds, and the fetch or distance over which the generating winds follow the waves without change of wind direction. For example, the waves generated by a small circular storm are not as damaging to the coastline as those from an oval-shaped storm in which strong winds blow from the same direction for several hundreds of miles. And in the same way the waves generated by a rapidly moving storm are

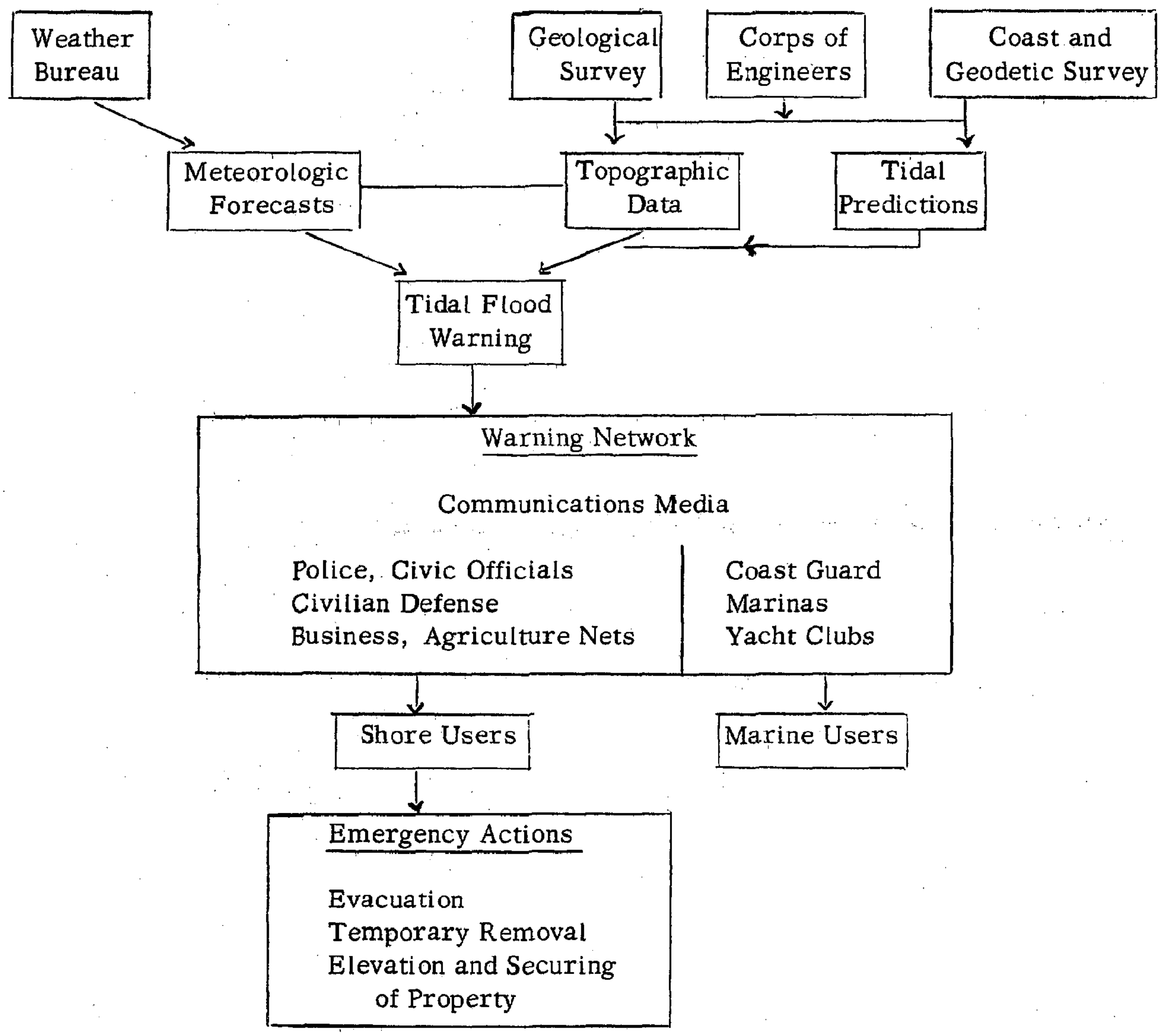

Figure 4-1. The communication chain for reduction of tidal flood damage by warning and emergency action.

generally less damaging than one which is stationary or slow moving, since the wind at any one locality changes its direction continually as the storm moves by.

"Experience and theory have provided reasonably effective tools for predicting the size of waves generated by winds of known strength, direction, and fetch. Thus if one can predict the development, strength, and geometry of storm winds, and the movement of the storm system, useful wave forecasts can be computed.

"A more subtle but equally important factor in coastal inundation, and the resulting loss of life and property damage, is the storm surge. This effect is one in which the tidal level of the sea is raised due to the accumulation of water transported by stresses of the wind on the sea. Wave action itself is responsible for little or no actual transport of water except when the churning wave motion touches bottom as it approaches the coast. However, the term "storm surge" refers to an unspecified number of effects which combine to transport and accumulate water along coastal regions. The storm surge associated with a hurricane may cause water levels to rise more than 15 feet above the level of astronautical tides. It is in this area of prediction that the greatest gap in knowledge exists, even though great progress has been made since studies of this effect were inaugurated in connection with hurricane research in 1956. Hence, if one knows the exact size and frequency of waves which will reach the shore, the extent to which damage will extend inland remains dependent upon the rise of water levels due to the storm surge.

"Finally, if meteorological prediction has been accurate, the computation of wave heights dependably determined, and the rise of water level due to the storm surge adequately anticipated, there remains an important problem of beach topography which may strongly influence the extent of inundation. This concerns the initial condition of beaches at the onset of the storm. If beaches are well stocked with sand to begin with, wave erosion may stop short of the protective dunes which in many areas act as a levee to inhibit massive flooding of the coastal plain. However, if the beach is already deeply eroded by earlier storms, the battering action of waves may extend far inland."[1]

But the problem of prediction is not the only one of concern. There is a question of interpretation as well. Consider this statement from the Weather Bureau forecast of 5 AM Tuesday, March 6, 1962 from the Washington Airport.

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[1] U.S. Congress, House of Representatives, 87th Congress, 2nd Session, Improvement of Storm Forecasting Procedures, Hearing before the Subcommittee on Oceanography, Washington: April 4, 1962, pp. 20-21.

"Tides caused by strong onshore winds will increase to 3 to 5 feet above normal today to the north of the storm center. This will cause extensive flooding in coastal lowland New Jersey northward into Southern New England today and tonight."[1]

An adequate interpretation of the warning by an individual coastal dweller would require both knowledge of the normal tides for the period and the elevation and expected runup at his own particular location. Except by experience such information is difficult to obtain. Only three maps designed to show coastal inundation specifically have been prepared and these were in the nature of an experiment.[2] To help bridge the interpretive gap, most Weather Bureau stations have developed detailed surge maps for use in local instructions. A series of surge warning maps for some of the coast has been developed by the Weather Bureau giving key elevations, critical causeway heights, information as to past inundation, and the like.[3]

The effectiveness of the warning network. How many shore users are reached by a warning? How many respond, and what is the nature of the response to a specific situation? The questions could not be readily investigated within the design of this study. But, it is possible from the interview data to derive a rough measure of aggregate responsiveness to the warning network and participation in emergency actions. From the respondents at the study sites, it was found that minimal emergency actions involving personal safety, or the temporary removal, elevation, and securing of property were very widespread. At least 60 percent of our respondents had employed them at some time. (See table 4-2.)

Table 4-2

Extent of Floodproofing Adjustments, by Type, 368 Respondents

Type of Adjustment	Number of Respondents	Percent of Total Respondents
Emergency actions, evacuation, elevation and temporary removal:		
Without prior preparation	224	61
Requiring prior preparation	10	3
Land elevation	10	3
Other structural changes	16	4

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[1] Ibid., p. 73.

[2] Ibid., p. 35. These were prepared for Atlantic City, N.J.; Providence, R.I., and Charleston, S.C. One additional map can be found in D. A. Crane, Coastal Flooding in Barnstable County, Cape Cod, Mass. (Boston: Mass. Water Resources Commission, 1962).

[3] An unpublished location diagram for storm surge warning maps lists 124 maps, 8-1/2 x 11, from 1:250,000 base maps, prepared or being prepared for the Atlantic and Gulf coasts.

Major public concern is with evacuation procedures which is as it should be, especially in areas subject to hurricanes. The Weather Bureau publication, "A Model Hurricane Plan for a Coastal Community,"[1] deals almost exclusively with planned evacuation. The most outstanding example of evacuation to date has been the Hurricane Carla experience, which saw over half a million persons evacuated from the Louisiana and Texas coasts in 1961.[2]

Emergency actions without prior preparation. Most emergency actions that may be taken in response to a warning involve little or no prior preparation. These include the removal of life and property from the path of the water, or taking protective action to minimize damages from actual inundation. The protection of property may involve "battening down" or various forms of placing portable property where it cannot be damaged. Some procedures are part of wintering routines of summer cottages. Simple adjustments involve the tieing up of boats or removal of lawn furniture; more elaborate ones might find furniture placed on a second floor.

Floodproofing

A comprehensive damage reduction program that employs combinations of minimal emergency actions, adjustments requiring more elaborate prior preparation, and permanent changes to structures has become commonly known as floodproofing.[3]

Emergency actions requiring prior preparation. Sixteen respondents employed the more elaborate emergency actions that require the advance stockpiling of special materials. By example, one commercial manager covered metal parts of machinery with grease to prevent rusting; another had constructed special crates to place around gasoline pumps to prevent their damage from floating debris. One householder constructed a special rig to use in elevating household appliances above flood levels.

Structural change. A more permanent set of adjustments involves changes to structures -- homes, commercial buildings, factories, and the like. These adjustments are basically of four types: (1) land filling and elevation designed to place buildings above the level of tidal floods, (2) anchorage devices designed to prevent structures from being washed away, (3) installations designed to keep water out of buildings and (4) measures to allow water through buildings to reduce buoyancy or hydrostatic pressures.

Many adjustments are incorporated into original construction. Land filling, elevation of structures, or deep piling (see figure 4-2) may be specified as part of the

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[1] U. S. Weather Bureau, "A Model Hurricane Plan for a Coastal Community," National Hurricane Research Project Report No. 28, U. S. Weather Bureau, 1959.

[2] Harry E. Moore, et. al., Before the Wind: A Study of the Response to Hurricane Carla, NAS-NRC Pub. 1095, 1963.

[3] Sheaffer, op. cit.

subdivision plat, in architectural plans, or in the course of replacement of previous damage. (See figure 2-12 for the extent of filling at the Dennis site.) But existing structures have been elevated as well. Interviews at Hampton Beach turned up two cases of elevation of existing structures (18 and 30 inches respectively). (See figure 4-3.) Similarly, anchorage devices are often provided as part of quality construction, but many have been installed as a result of subsequent experience. At Bethany Beach one resident tied down his building with steel cables as a kind of land anchor.

More difficult to effectuate are provisions to keep water out of structures. This type of floodproofing technology is now partly developed for riverine situations, but the structural requirements for successful sealing are stringent. The wood construction most commonly found along the shore does not lend itself well to this type of adjustment. Still, several examples of attempts to keep water out, using special doors combined with sandbags, or even bath towels, were discovered in the course of interviewing. Equally common and more adapted to coastal construction were adjustments designed to let the water run through. The use of piling was common. Other examples including the construction of a special trapdoor to let water out were observed. It should be noted that unlike land elevation, some of these adjustments require action after a warning in order to initiate them, i.e. opening a trap door, placing sand bags, etc.

Altogether, there were 10 cases of land filling and 16 examples of other structural adjustments among the 368 interviewed shore users. (See table 4-2.) While these provided evidence of the wide range of adjustments and testimony to individual ingenuity, most coastal dwellers and commercial interests place their main reliance on protective works.

Protective Works

Major reliance for the prevention or reduction of tidal flooding is placed on protective works of various types. In the main, there appear to be two types of works; those that attempt to bar the passage of surges by artificial means, bulkheads, seawalls, and revetments; and those that attempt to use the natural defenses of beach and dune. The sloping beach up to and including the berm is usually considered the outer line of natural defense. Sand dunes which normally absorb a great deal of wave energy are considered an inner natural defense.[1] To maintain these inner and outer defenses, groins and jetties are constructed, beaches artificially nourished, and dunes are built and stabilized.

All protective works interfere with natural shore processes and their impact and effectiveness varies. The state of the coastal engineering arts seems to be continuously improving but the shore is littered with earlier structures whose effectiveness has been obviously impaired or that have apparently created problems equal or even greater than

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[1] U.S. Army Coastal Engineering Research Center, Land Against the Sea, Miscellaneous Paper No. 4-64, May 1964, pp. 23-33.

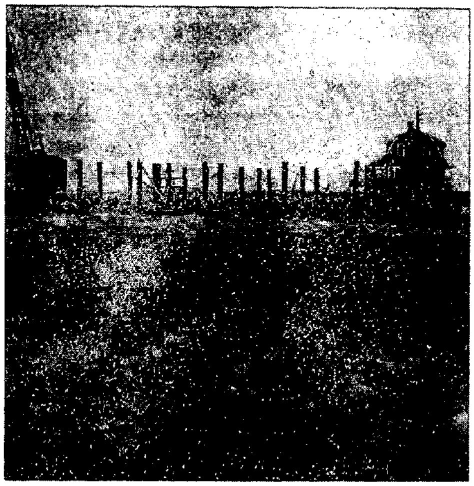

Figure 4-2

At Bethany Beach, piling is being driven deep into the sand upon which a house will be built. When properly designed, this construction is well suited for a shore location providing excellent views and protection at the same time.

Figure 4-3

View of marsh fill at Hampton Beach, New Hampshire. Fill is placed on the landward side of the barrier bar. Houses raised above the fill are still subject to flooding during severe storms.

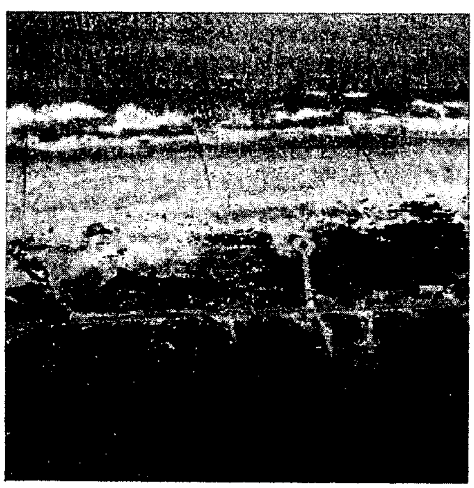

Figure 4-4

Air view of groins in southern New Jersey. At this particular period, fall 1964, waves are coming directly onshore and material is evenly spread along the beach.

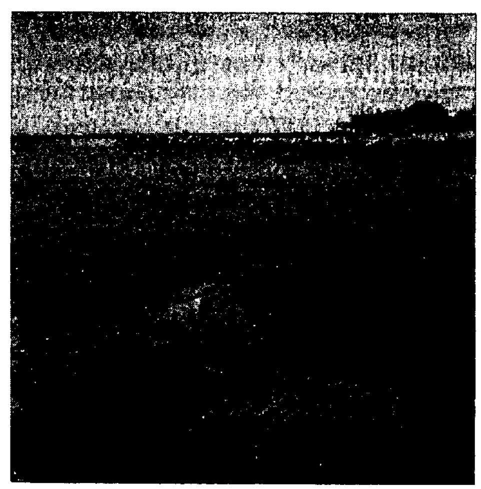

Figure 4-5

The jetties at Point Judith which protect the inlet between Point Judith Pond and Block Island Sound connect with a large breakwater which forms the Point Judith Harbor of Refuge. The buildings on stilts in the background are part of the town of Jerusalem.

those they were intended to solve. Some specific examples observed at the study sites are cited in the detailed discussion of protective works that follows.

Groins. The walls or fences installed across the beach from the dune or bulkhead down to, in some instances, a 6-foot depth in the ocean, are called groins. (See figure 4-4.) They are built both to retain the beach by interfering with lateral transport and to help build it up by trapping sand between them. As early as 1898 these structures were being built along the Atlantic coast to help improve beach conditions and today, groins comprise about 90 percent of the major engineering structures found along the study shore. They are found most frequently in New Jersey, Connecticut, and Massachusetts while Virginia, Maryland, and North Carolina have groins only near beach resorts where beach erosion is a serious problem. In New Jersey, the state with the largest number of groins, about 64 miles of the total 150 miles of coastline are protected by them. More than 200 groins can be counted along this coast. [1]

The effects of groin construction can be illustrated by its history at Bethany Beach, Delaware where recession of the shoreline has averaged nearly three feet per year since 1843.[2] The problem is particularly serious at Bethany Beach because the littoral supply of sand is limited. Ocean currents move away from this section of the coast both towards the north and the south.

In 1929 nine groins were built along the beach front of this resort and shore erosion since then has been lessened. Generally the nine groins at Bethany Beach showed accretion on the south side in summer and on the north side in winter with the net accretion indicating a slight northerly littoral drift. But changes in the contours of the coast indicate that there has been an average over-all loss of about 8 feet per year. Along one critical mile of beach approximately 20,000 cubic yards annually is removed. It appears that this particular section of the coast has been a supplier of sand to other parts of the Eastern Shore of Delaware, Maryland, and Virginia.

When groins were first built along the east coast of the United States it was generally believed that the sand came from offshore and that a groin would create a beach regardless of other factors. But in reality most sand is derived from headlands or nodal points and transported along the immediate shore by longshore currents. Many groin fields have obstructed the normal movement of sand and helped to dry up the so-called stream of sand. Thus, groins in a number of instances have done great damage to adjacent sections of shore. This appears to be the case at Bethany Beach. A design now permits the stream of sand to pass over the top of the groin and to continue downstream to nourish neighboring shores. It is hoped that these will perform better.

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[1] U.S. Army, Coastal Engineering Research Center, "A Pictoral History of Selected Structures Along the New Jersey Coast," Miscellaneous Paper No. 5-64, October, 1964, Dept. of the Army, Corps of Engineers.

[2] Corps of Engineers, Delaware Coast from Kitts Hummock to Fenwick Island, Beach Erosion Control Study, 85th Congress, 1st Sess., House Doc. No. 216, 1957, pp. 21, 29, and 35.

Jetties. Jetties are built to modify or control sand movement at navigation openings. When sand moves zigzag along the beach and arrives at an inlet it flows into the opening and is carried inward on the flood tide to form an inner bar and out on the ebb tide to form an outer bar. Both of these bars are navigational hazards. In many ways a jetty is similar to a groin, but usually the jetty is larger and completely blocks all sand movement along the coast. Nearly all of the inlets along the east coast of the United States have some type of protective work, usually a rock jetty.

These structures are major sources of sand depletion along the coast because when no jetties exist sand is transported intermittently across the inlet to help feed the downstream side of a beach. Attempts are now being made to dredge or pump the sand through pipelines across the inlets. A good example of this is at Absecon Inlet in New Jersey where sand from Brigantine Island is being pumped across the inlet to supply the beaches at the north end of Atlantic City. This process appears to be much too slow and costly, and it is a never-ending task.

Study sites where jetties are particularly important in protecting inlets include: Wildwood Crest and Cape May where the jetties at Cold Spring Inlet protect the entrance to the Cape May Canal; Bethany Beach where jetties protect the entrance through Indian River Inlet; Point Judith where the jetties protecting the entrance to Point Judith Pond have been extended to form a breakwater and a harbor of refuge; Dennis where jetties protect the entrance to the Bass River; and Hampton Beach where jetties line the entrance to Hampton Harbor Inlet.

Breakwaters. These structures are constructed mainly for navigation purposes and have both beneficial and harmful effects on the shore. Usually a breakwater is a stone wall, up to 10 feet high, built to inclose a harbor area and then connected to the shore to provide a shelter for boats. It acts like a jetty in that it obstructs the free flow of sand along the coast and has been known to starve the downstream beaches of material.

Breakwaters are found at several of the study sites. The best example of a large breakwater is at Point Judith, Rhode Island where a 4- to 5-foot high rock wall has been built over a mile seaward. This stone wall helps absorb the energy of storm waves but does not protect from flooding. (See figure 4-5.)

Beach nourishment. As more of the Atlantic coast is protected by structures, less sand is available to fill the areas between groins and jetties. It is now the policy of the Corps of Engineers to place sand artifically on the beach. There seems to be a growing realization that in the long run the best methods of beach growth must be as similar as possible to natural ones. To simulate this natural protection, dunes and beaches are rebuilt artificially. Sand sources in the lagoons and marshes behind the beach are transported by pumping across the barrier islands onto the beach. Artificial beaches have been built in this manner at the Sandy Hook, Cape May, and Hampton Beach study sites.

The Bethany Beach site, previously discussed in connection with its groins, has also been the site of substantial nourishment. Because of the gradual erosion at Bethany Beach the Corps of Engineers proposed in 1957 to truck-haul 78,000 cubic yards of beach fill in order to make a beach 4,800 feet wide. The plan was then to add annually an average of 20,000 cubic yards of sand by truck-haul from a source one mile away on the lagoon side of the barrier island.

But beach filling is not always nature's requirement to detain beach erosion. Figure 4-6 shows that in one storm at Bethany Beach in the summer of 1962, over half of the new 20,000 cubic yards of beach fill trucked onto the beach in the spring was eroded away. Part of this sand was returned during the next few weeks under calmer conditions, but the beach was not returned to its former width or height. Since this section of coast appears to be an area of natural erosion from which sand is moved north and south along the coast, its nourishment would be a continuing task.

Land stabilization. As man has sought to improve the outer defenses by groins and nourishment, there has been a belated recognition of the need for protecting the inner defenses, as well. Dunes come under the attack of wind, water, and increasingly, the bulldozer. Unfortunately efforts to deal with the bulldozer appear limited, but numerous state and federal projects are now underway to hold the sand on the barrier islands and to help sand dunes to grow.

At a number of places along the East Coast, including at least five of the study sites, sand fences have been erected to trap the sand as it blows from the beach. Cape Hatteras National Seashore, which is at the southern end of the Nags Head study site, is an area where dune building has been very successful.[1] After the March 1962 storm, bulldozers pushed sand from the foreshore to the backbeach to form a line of high dunes. On top of these dunes, fences were placed to trap the sand. Figure 4-7 shows four foot fences laid out 300 feet from mean high tide. As the dunes build up (and sometimes it takes only one year to bury the fence) a new line of fences are placed 16 to 20 feet closer to the shore.

On top of the newly formed dunes, grasses such as American beach grass (Ammophila breviligulata) and sea oats (Uniola paniculata) are often planted. The grass is usually planted by hand or by machine but at Bethany Beach the dunes were seeded and fertilized by plane. In figure 4-8 private individuals have planted grass by hand in front of summer homes. One motel owner in Wildwood Crest has put down bales of hay, covered it with sand, and planted dune grass on top. The grass is doing very well because the hay holds the moisture and protects the plants from wind erosion while they are young. At Nags Head, Assateague, Bethany Beach, Sandy Hook, Wellfleet, and Montauk major efforts are being made to stabilize the backbeach with grass.

Bulkheads, seawalls, and revetments. When man first settled along the shore adequate beaches and dunes served to protect the shore developments. An occasional

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[1] Edward Nash, "Beach and Sand Dune Erosion Control at Cape Hatteras National Seashore," U.S. Department of the Interior, National Park Service, Cape Hatteras National Seashore, Manteo, N.C., 1962, pp. 4-12.

severe storm would cause beach erosion, the opening or closing of an inlet, or the removal of dunes, but nature would heal these wounds during the calmer summer months. All barrier bars, being temporary wave-built features, were subject to these changes.

As barrier bars were settled, dunes were removed to provide unobstructed views of the sea and to provide level land. The removal of the dunes enabled storm waves to reach deep into a barrier island. Man soon discovered that some protection was needed. He turned to walls of various types as a partial substitute for the dunes he had destroyed.

The walls, called bulkheads, served as a secondary line of defense behind the beach which was the first line of defense. These structures are constructed of concrete, steel, or timber piling. It was found over time that the bulkhead acted only as a temporary solution because the beach continued to retreat and large waves would cross it. The bulkhead evolved into a massive seawall, capable of withstanding the direct force of the waves. Such a massive seawall is shown at Sandy Hook, New Jersey, figure 4-9.

Large numbers of these seawalls have been built along the east coast of the United States. In every one of the study sites where numerous structures occur close to the beach there is usually some type of bulkhead or seawall.

But in developing this type of protection it has been found that while these obstructions might protect structures behind them, they have little influence in holding or protecting the beach which in the long run is the greatest asset of shorefront property. In fact, a seawall is detrimental to the beach because as waves strike against the wall the backwash will cut away the beach in front of it. Often a stone apron has to be built out in front of the structure.

A revetment consists of covering the sloping face of a dune or bluff with one or more layers of rock or concrete. This type of structure dissipates wave energy with less damaging effect on the beach than is caused by waves striking vertical walls.

At several of the study areas a boardwalk serves as a seawall because it helps break the energy of storm waves. The boardwalks at Bethany Beach and Cape May helped to deter wave energy during storms. However, at both sites the boardwalks were very heavily damaged in the March 6-7, 1962 storm. (See figure 4-10.)

Bulkheads, seawalls, and revetments are the favored substantial adjustment undertaken by individuals along the shore. However, most of these individual adjustments were modest in size and design, and often constructed to prevent erosion or keep sand off lawns as much as to prevent tidal flooding. (See figure 4-11.)

At Cape May, New Jersey, the boardwalk which was destroyed is being replaced with a large bulkhead. Construction of this seawall (figure 4-12) consists of putting in an 8-foot high wall of steel piles, then placing large boulders around it and covering the whole structure with concrete. A 10-foot high completed section is shown in an air photo in figure 4-13. It can be noted in the picture that the seawall is under heavy pounding by waves

Figure 4-6

In July 1963 a moderate storm off the Delaware coast cut away the beach fill at Bethany Beach. In two days time much of the sand was replaced by a calm sea, but the beach did not return to its former size.

Figure 4-7

At Nags Head, a line of sand fences have been put up to trap sand and help build up the dunes. When this set of fences is buried a new line will be placed 16 to 20 feet closer to the shore.

Figure 4-8

View of hand planted American beach grass (Ammophila breviligulata) at Bethany Beach, Delaware. The grass will grow best when new sand moves around it and forces it to grow taller.

Figure 4-9

View of the 10-foot rock bulkhead at Highlands Beach, Sandy Hook study site. This is a new stone wall built to an elevation of 10 feet above mean sea level. Damaged jetties are shown in the distance.

Figure 4-10

View of the board walk at Cape May, New Jersey several weeks after the March 6-7 storm. Planks of the board walk were carried across the street against buildings. Cape May pier was very heavily damaged.

Figure 4-11

At Fairfield, Connecticut study site residents have constructed their own form of groins and bulkheads. Part of their structures have suffered damage as shown by the posts sticking out of the water.

Figure 4-12

The new bulkhead being built at the eastern end of Cape May will consist of steel piling, then large boulders on both sides, and on top of this cement. A section of the nearly finished bulkhead is in the foreground.

Figure 4-13

Air view of the completed 10-foot bulkhead at Cape May, New Jersey. Note that a sandy beach is completely lacking from this section of the coast. Residences and hotel facing the sea suffered minor damage in March 6-7, 1962 storm.

with almost no beach in front of it. Great erosion is taking place along this section of the coast.

Study sites, other than Sandy Hook and Cape May, where large bulkheads and seawalls have been built include Hampton Beach, and Point Judith. At Chincoteague a low dirt seawall has been constructed on the northwest shore of the island.

Extent of protective works. Some of the many problems that arise from inadequate understanding of, and basic interference with, natural shore processes have been recounted in the foregoing passages. But these should not deny the proven effectiveness of protective works in certain situations.

In order to provide an order of magnitude estimate of the prevalence of use, a rough tabulation was made of the length of coast in each state from Maine to South Carolina with some type of protection through engineering structures. These figures are shown in table 4-3. Of the 1095 miles of outer coastline tabulated, approximately 240 miles or roughly 23 percent of the coast has some type of protection by either groins, jetties, bulkheads, seawalls, or revetments.

The tabulations were based on various official studies of the Corps of Engineers including Beach Erosion Board reports and hurricane studies. The estimates are necessarily crude because:

1. Only large structures built by either the Corps of Engineers, state governments, counties, or cities are usually shown in Beach Erosion Control reports. All small seawalls, bulkheads, etc. built by private individuals are not included.

2. Data were lacking for sections of the coast, especially the north shore of Long Island and sections of Massachusetts. Because of this the measured coastline was 1095 miles instead of 1302 miles.

3. In measuring the length of coast it was difficult to define the extent of coastal protection. An example is Wildwood Crest where jetties built at Cold Spring Inlet at the entrance to Cape May Canal have resulted in sand being deposited north of the jetty forming a wide beach at Wildwood Crest. As the wide beach is the direct result of jetties this section of coast is considered protected, but the lineal extent is difficult to measure. (See note on table 4-4.)

Table 4-3 shows that the New England and Middle Atlantic states have the bulk of the protective works. The state with the largest number of engineering structures is Connecticut with 68.5 miles of coast, roughly 50 percent of its entire outer coastline protected by man-made structures. New Jersey is a close second with 68 miles or roughly 45 percent of the coastline having protective works.

Table 4-3

Coastal Engineering Structures and Protective Works Along the East Coast of the United States from Maine to South Carolina

State	Length of Coast in Miles	Length of Coast Protected	Percent
New Hampshire	17.0	8.2	48
Massachusetts	116.0*	40.0	35
Rhode Island	51.5	21.0	41
Connecticut	137.5	68.5	50
New York	125.0*	22.3	18
New Jersey	151.5	68.0	45
Delaware	25.0	1.8	7
Maryland	31.5	0.2	1
Virginia	113.0	3.0	3
North Carolina	327.0	7.0	2
Total	1095.0	240.0	23

*Of the total 370 miles of Massachusetts coastline only 116 miles were examined for engineering structures, and of the total 307 miles of New York coastline only 125 miles along the south shore of Long Island were studied.

The portion of total coastline protected decreases rapidly south of New Jersey. Maryland with a total coastline of 31.5 miles has only 0.2 miles protected at Rehoboth Beach. For Virginia the resort of Virginia Beach has a few structures, mainly a series of bulkheads. Of the 327 miles of North Carolina coastline only 7 miles have any type of protective works. At Wrightsville Beach and Carolina Beach there are a series of groins built to trap sand and protect the beach from erosion. Nags Head has several piers which were badly damaged in the March 6-7, storm in 1962, but their presence offers some protection to the structures behind them.

With the growth of resorts, especially along the eastern shore of Virginia and in North Carolina, the most likely adjustment to the hazards of erosion and storms will be the construction of more and more engineering works. The striking result of this survey is the similarity between the estimated percent of shore frontage developed, 21 percent, and the crude estimate of percent protected, 23 percent.

Protective works at the study sites. Table 4-4 is a tabulation of engineering structures and protective works found at the 15 study sites. Although a more accurate count of the structures at each of the study areas can be given than for the outer coastline stretching from Maine to South Carolina it is still difficult to estimate the length of coast protected by a single jetty or groin. At several study sites, for example, Sandy Hook, New Jersey, the series of groins built at Sea Bright affect the entire coast to the north even though few protective works continue to the tip of the spit.

Table 4-4

Coastal Engineering Structures and Protective Works
at the 15 Study Sites

Study Site No.	Name	Length of Coast	Length of Coast Protected	Percent of Coast
1.	Point Judith	8.3	3.5	34
2.	Wellfleet	5.8	0	0
3.	Villas	1.3	1.0	77
4.	Chincoteague	17.0[1]	2.4	14
5.	Lynn-Nahant	7.2	6.4	88
6.	Fairfield	4.0	3.2	80
7.	Hampton Beach	4.3	2.3	53
8.	Montauk	8.4	.4	6
9.	Sandy Hook	6.8	5.3	77
10.	Cape May	1.6	1.6	100
11.	Wildwood Crest	3.7	3.7[2]	100
12.	Dennis	4.4	3.5	79
13.	Nags Head	9.3	.3	14
14.	Bethany Beach	7.5	.6	8
15.	Assateague	7.1	0	0
	Total	96.7	34.2	35

[1] Although the island of Chincoteague is not on the ocean, the length of shoreline around the island is given in miles.

[2] The growth of the beach at Wildwood Crest is the result of jetties built at Cold Spring Inlet. Therefore, the beach has been indirectly widened and protected by engineering structures.

Of the 96.7 miles of coastline included in the 15 study areas, approximately 34.2 miles or 35 percent of this coastline is protected. This higher percentage in comparison with 23 percent for the over-all coastline from Maine to South Carolina comes from the more intensive use of the study sites as summer resorts, urban communities, and villages requiring protective works.

A second measure of the wide prevalence of protective works come from the shore user interviews. (See table 4-5.) Thirty-two have constructed some type of structure, although often quite modest, as in the brush revetment at Bethany Beach shown in figure 4-14. Land stabilization practices were employed by twelve respondents and some were quite elaborate. But to be truly effective, protective works need good design and maintenance. This freqeuntly exceeds the ability of individuals or even individual communities.

Table 4-5

Extent of Adjustment by Protective Works,
368 Respondents

Type of Adjustment	Number of Respondents	Percent of Respondents
Groins, seawalls, bulkheads or revetments	32	9
Land stabilization	12	3
Special activity to secure community protection	15	4

Therefore, as part of their individual adjustments, many shore users turn their attention to the long and time-consuming process of securing public assistance rather than attempt to construct protective devices. The interviews turned up many instances of participation in improvement organizations, writing letters, attending meeting, and the like. In addition, some fifteen respondents were especially active in trying to secure protection; many having made trips to Washington or to the state capitol.

One interesting facet of the agitation for protection, and somewhat unexpected initially, was the prevalence of similar agitation against protective works. It almost appeared that every jetty had its proponents and opponents, depending on which side of the drift they lived. In a sense, this opposition mirrors the misgivings shared by the many technical experts and the authors themselves as to the desirability of protective works. There is no denying the effectiveness of a massive seawall against tidal flooding; the concern is with the cost, including long term costs not initially foreseen, and the paradoxical destruction of some of the amenities desired to be protected. The cottages shown in figure 4-15 at Hampton Beach are protected by an old and partially destroyed seawall and a new steel pile bulkhead, but the view of the seawall from the cottage window and the scant beach do not add to the attractiveness of the location. Thus it is not surprising to find reluctance upon the part of communities to implement apparently well designed engineering plans. The most outstanding case was Fairfield, Connecticut.

At Fairfield, the expressed opposition was not against protective works per se, but against the specific seawall and its size. Residents tried to resolve the problem of need for protection and yet loss of attractiveness by suggesting that the wall, if it should be built, be a "small" one. In its most extreme form, the desire for amenity actually increases hazard as in the case of extensive dune leveling to improve the view.[1]

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[1] A more recent example is found in the May 20, 1965 issue of the New York Times when "residents of Long Beach, Atlantic Beach, and Lido Beach turned out today to object to a proposal by the Army Engineers to build a 10-mile-long, 100-foot-wide sand dune across the ocean front communities" in a hearing marked by "personal attack" and "persistent boos and hisses" directed to the representatives of the Corps of Engineers.

Figure 4-14

At Bethany Beach, Delaware, brush in front of a private residence serves as a revetment. The owner hopes that sand will pile up against this type of wall and help stabilize the man-made fill behind it.

Figure 4-15

The cottages shown in this picture at Hampton Beach, New Hampshire were formerly protected by a sea wall, now partially destroyed as shown in the foreground. The new steel pile bulkhead behind the sea wall obstructs the view and probably accounts for the skimpy beach.

Land Use Change and Control

The final set of adjustments employs a variety of devices to guide land use in a direction that will reduce damage from tidal flooding. The devices themselves are fairly standard, based in law upon the responsibility of a community for health and welfare, and employing both police power and the right of eminent domain. A community or state employing them may purchase land outright, specify permitted uses through zoning ordinances, or control building elevation and construction through zoning ordinances and building codes.[1]

Purchase of land. Outright purchase of land to reduce tidal flood damage is apparently extremely rare or nonexistent. More common is the purchase of land for public uses, frequently recreational, which also leads to low damage patterns of land use. The prospective establishment of the Assateague National Seashore, while intended primarily for recreation, has been given urgency because of the impending subdivision and construction on the Maryland portion of Assateague Island. The National Park Service urges establishment of the seashores and other recreational areas to reduce potential tidal flood damage.[2]

Zoning ordinances. The major device used for control of land use is the zoning ordinance. Three types of zones have been suggested for riverine flood plains and the classification would seem appropriate for coastal areas as well.[3] The first is a prohibitive zone within which all permanent structures would be banned except those requiring direct adjacency to water. Such a zone is provided for in the Warwick, R.I. ordinance.[4] Identified as an area of "extreme hurricane danage," all structures are banned within it except non-commercial boating docks.

The second zone is a restrictive zone in which certain uses are permitted and others are banned. The Warwick ordinance provides an example of one variant of the restrictive zone. There, a zone identified as a zone of "hurricane danger" provides a minimal structure elevation, "no building shall be lower than 15 feet above mean sea level." The minimum elevation device is common in restrictive zones as is the alternative of enumerating uses as in the Fairfield, Connecticut ordinance.[5] Permitted uses

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[1] See extensive literature cited in bibliography of Tennessee Valley Authority, op. cit.

[2] U.S. National Park Service, Region Five, Seashore Preservation and Recreation Opportunities and Storm Damage, April 1962.

[3] Robert W. Kates and Gilbert F. White, "Flood Hazard Evaluation," Papers on Flood Problems, op. cit., p. 142.

[4] City of Warwick, R. I., Zoning Ordinance, Section 3, City Council, 1958.

[5] Fairfield, Connecticut, Zoning Regulations, Section 22, Town Plan and Zoning Commission, p. 13.

in the "Flood Plain District" are parks, playgrounds, marinas, boathouses, landings, docks, clubhouses, and accessories. In both cases the underlying rationale seeks either to encourage the elevation of structures or the limitation of land use to low damage uses where structures are not elevated.

A third zone more theoretical than actual is the warning zone. Here the hazard is of such a nature that the community would desire to provide warning, but only as guidance to land users. No specific instances of such zones are known to the writer, but in one sense, the area shown subject to tidal flooding on map sheets such as the Atlantic City sheets or Providence, Rhode Island serves this function if they are widely distributed.

Building codes that specify a fixed elevation or storm resistant construction, may serve the same desirable ends as the restrictive zoning ordinance, In addition special regulations relating to filling of tidelands, protection for shellfish or navigation channels may have some slight effect on damage reduction.

Nature herself may be an instrument of land use change by the destructiveness of storms themselves. The 1938 hurricane cleared much of the property out of low-lying areas at Guilford, Connecticut and these have not been rebuilt. This may be more effective where the power to prevent rebuilding is established as in the Rehoboth Beach ordinance[1] and is exercised to reduce future damage potential.

The employment of land use controls to reduce tidal flood damage is not extensive. A nine month inquiry directed to 150 communities most likely to be subject to damage elicited only fifty replies and ten examples of specific flood plain regulation. Eleven communities referred to coastal hazards without making specific regulatory provisions. Sixty percent of the responding communities had no regulations relevant to coastal hazard. (See table 4-6.)

While the survey was in no way comprehensive it was strongly biased in favor of potential respondents that might have adopted land use controls. First relevant state agencies were canvassed from Maine to North Carolina for information relating to land use guides and controls. Based on their replies and suggestions, the 150 communities were chosen. The letters to local planning authorities were most likely to be answered by those communities that had taken action, they naturally being most eager to share their experience. Thus it might be safely inferred that the limited use of land use guides revealed by the survey is characteristic of the entire study area.

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[1] <u>Zoning Code for the City of Rehoboth Beach, Delaware,</u> amended 1953, Ordinance No. 68, Sec. 804, p. 18.

Table 4-6

Extent of Land Use Controls to Reduce Tidal Flood Damage

State	Agencies Responding	Specific Flood Plain Regulations	Some References to Flooding in Plans	No Reference to Flooding
Connecticut	10	4	2	4
Massachusetts	12	1	2	9
New Jersey	2	1	0	1
New Hampshire	0	0	0	0
Maine	4	0	1	3
Delaware	2	0	1	1
New York	11	1	4	6
Rhode Island	2	2	0	0
North Carolina	5	0	1	4
Maryland	2	1	0	1
Totals	50	10	11	29

CHAPTER V

THE CHOICE OF ADJUSTMENT

The range of adjustment is broad; but neither public agencies nor private interests seem to combine adjustments adequately into a comprehensive program for damage reduction. This chapter inquires into the process of choice employed both in the public and private sectors. However, a necessary, if not sufficient condition for choice among adjustments is a motivation to reduce hazard. This can only come from a perception of danger and a knowledge of the available means for hazard reduction. Therefore, a first concern is to explore and measure the perception of hazard from coastal storms.

The Perception of Storm Hazard

Public perception. In one sense any public manifestation of the awareness of the hazard from coastal storms is an expression of public perception. A local newspaper editorial anticipating the hurricane season, or a small craft warning flying from the Coast Guard masts are examples of public display. Rather than catalogue the obvious, the public perception is best exemplified in the expression of the national policy found in Public Law 71 adopted in 1955.

> "Sec. 1. . . . That in view of the severe damage to the coastal and tidal areas of the eastern and southern United States from the occurrence of hurricanes, particularly the hurricanes of August 31, 1954, and September 11, 1954, in the New England, New York, and New Jersey coastal and tidal areas, and the hurricanes of October 15, 1954, in the coastal and tidal areas extending south to South Carolina, and in view of the damages caused by other hurricanes in the past, the Secretary of the Army, in cooperation with the Secretary of Commerce and other Federal agencies concerned with hurricanes, is hereby authorized and directed to cause an examination and survey to be made of the eastern and southern seaboard of the United States with respect to hurricanes, with particular reference to areas where severe damages have occurred.
>
> "Sec. 2. Such survey, to be made under the direction of the Chief of Engineers, shall include the securing of data on the behavior and frequency of hurricanes, and the determination of methods of forecasting their paths and improving warning services, and of possible means of preventing loss of human lives and damages to property, with due consideration of the economics of proposed breakwaters, seawalls, dikes, dams, and other structures, warning services, or other measures which might be required."[1]

[1] Public Law 71, 84th Congress, approved 15 June 1955.

The law is evidence of public awareness that a problem exists and authorizes the making of a more technical appraisal of hazard for the purpose of public action.

A technical appraisal of hazard. In earlier chapters, aspects of the scientific-technical problem of hazard appraisal were reviewed. In one instance, the problem of prediction as envisioned by the Weather Bureau was set forth (see p. 552), and Chapter III represents a large-scale attempt to appraise the hazard potential of the east coast. These problems of prediction and appraisal are very germane to the over-all problem, but not necessarily related to the situation of the manager of a shore front property - the owner, renter, or public agent who seeks to reduce his damage potential. Prediction is, of course, required for the adoption of emergency actions but the uncertainties of prediction do not enter into the consideration of other long-term adjustments. Thus the problem of forecasting the direction that a unique storm will follow need not be considered in making a decision to build a seawall. Rather, some average expectation of direction, fetch, and wave height is required. Or consider the problems raised in Chapter III. The difficulty of generalization as to tide height and damage for the entire shore can be resolved for a single small area in terms of the peculiarities of topography, prevailing wind, and the like.

Thus, a more appropriate model of how technical appraisal of hazard takes place might be derived from a description of current practice of the Corps of Engineers in designing protective works for a single area. Such practice, while less than the ideal or even best scientific technique, being constrained always by problems of funds and personnel, does provide a hazard appraisal to which private perception of hazard can be compared.

The Corps estimate of its own capabilities is as follows:

> "Since 1955 the Corps has intensified its research in the field of protection from major storms, particularly those of hurricane force. As a result there is now sufficient technical knowledge available to predict the height of storm tides and waves, as well as the damage they would be capable of inflicting, for almost any specified locality and for any storm of specific magnitude and duration."[1]

A recent example of such an appraisal might be taken from the interim hurricane survey of Stratford, Connecticut.[2] The hazard appraisal begins with a historical review of hurricanes going back to August 15, 1635, and a rough description of hurricane frequency. Specific characteristics of hurricanes: origins and tracks, winds and barometric pressure, rainfall, waves, and tidal surges are examined. But these materials are background or illustrative. The crucial calculation is the development of the "Standard Project Hurricane." This is defined as a storm that may be expected from the most severe combination of meteorologic conditions that are considered reasonably characteristic of the region involved,

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[1] U.S. Army Coastal Engineering Research Center, Land Against the Sea, Miscellaneous Paper No. 4-64, May, 1964, p. 10.

[2] U.S. Congress, Stratford, Connecticut, An Interim Hurricane Survey, House Document No. 292, 88th Congress, 2nd Session, 1964, pp. 20-38.

excluding rare combinations. The estimated frequency of such a Standard Project Hurricane is not found in the published report. The Standard Project Hurricane is derived in the case of Stratford by transposition of the hurricane of September 1944, which had, off Cape Hatteras, the greatest energy known of any hurricane along the Atlantic Coast.

The hurricane was routed over water to provide high estimates of storm surges along the Connecticut shoreline of Long Island Sound -- 1.4 times the recorded surge of the September 1938 hurricane. This hurricane surge was then placed on top of a spring tide to give a design tide level of 13.2 feet msl or 4.0 feet higher than the levels of flooding actually experienced in 1938 and 1954.

While unpublished estimates of frequency are apparently made in connection with economic analysis , no expression of frequency is provided other than a listing of the number of hurricanes in historical times. The emphasis in the hazard appraisal is placed on the estimation of maximum values of hazard for use in constructing engineering works that possess only very small probabilities of failure. Hazard appraisals for economic optimization or land use guidance, probably within the technical competence of the Corps, are not routinely provided by Corps reports.

Private perception. Compared to the procedures of the Corps in appraising hazard, which start with careful reconstruction of past experience, then include extension beyond actual experience by storm transposition, and the combination of extreme conditions of tide and surge, the perception of hazard by most managers of shore front property must appear rudimentary at best. This primitive appearance stems not only from the actual appraisals made by individuals but may be exaggerated by the interviewing procedures used to identify these private perceptions. The interviews themselves provide only rough insights into the surely complicated ways in which people perceive hazard.

Interviews at the study sites. At fourteen of the fifteen sites (omitting the empty shore) over 1,000 interviews were taken from a variety of shore users. Of this group, 371 interviews were made with managers of property, those who controlled the use of an establishment found on the study shore. These managers were in three groups; owners of seasonal residences, owners of year-round or permanent residences, and commercial establishments. The sample at each site was not selected by random process and it fluctuates in size from 9 interviews at Wellfleet to 44 interviews at Chincoteague. The residences or businesses selected for interview were chosen to provide variation in elevation and hazard, and variation in the characteristic land uses found at each site. In contrast with the air photo sampling procedure, the lack of random selection was not considered critical as estimates of the characteristics of all shore users were not intended. Rather, the field workers were instructed to carry out, within a time constraint, a sufficient number of interviews to provide for the interviewer an understanding of the preception of hazard and modes of adjustment to be found at the study site. This was done, and these understandings have been incorporated into the case studies. For this section, the 371 interviews will be considered as a group of characteristic users of the shore but not necessarily representative of the entire study shore. Informative data about these respondents are presented in table 5-1, along with comparative characteristics of the general population. The interviews

Table 5-1

Characteristics of Respondents in Study Site Interviews

Characteristics	Number of Respondents	Percent	U.S. Population Percent[a]
(371 respondents)			
Seasonal Resident	114	31.7	-
Permanent Resident	127	34.2	-
Commercial	130	35.0	-
Education: (230 respondents)			
Grade (0- 8 yrs. completed)	31	13.5	39.6
High School (9-12 yrs. completed)	99	43.1	43.8
College (13+yrs. completed)	100	43.5	16.5
Income: (198 respondents)			
less than $ 2,999	26	13.1	20.5
$ 3,000 - 5,999	38	19.2	30.2
6,000 - 7,999	37	18.7	18.2
8,000 - 14,999	53	26.8	23.9
15,000 and over	44	22.2	7.2
Elevation of 1st Floor Relative to Maximum Tidal Flood: (274 respondents)			
More than 1 ft below	51	20.8	-
Within 1 ft of maximum tidal flood	176	64.2	-
More than 1 ft above	41	15.0	-

[a] From Statistical Abstract of the U.S. 1964, pp. 113, 338

are divided almost evenly among permanent residents, seasonal residents, and commercial managers. It is quite evident that the users of the shore are considerably above the national average in education and income, a not unlikely finding considering that many were owners of second homes or prosperous businesses.

The elevation of the first floor of the home and business relative to the height of the maximum tidal flood is shown in the table as well. These elevations were estimated by the field parties using topographic maps as a guide. They have been grouped into three general classes: more than one foot below the height of the maximum tidal flood, within one foot of the height of maximum tidal flood, and more than one foot above the height of maximum tidal flood. Fifteen percent of the respondents had 1st floor elevations at least one foot above the maximum tidal flood.

Respondents' Perception of Storm Hazard

Perception or awareness of storm hazard has two components: (1) the evaluation of past experience, and (2) the expectation of future storms. Just as the technical appraisal seeks to identify the historical record of storm experience, respondents evaluate and assimilate what they know about storm hazard and what they have experienced. In seeking to identify these experiences it is not sufficient to conclude that a respondent experienced hazard because he happened to live at the site at the time of some major storm. Rather, it requires the recognition of the storm as such, by the respondent. As will be shown not all respondents accept the common appraisal of a storm.

But if one accepts as a definition of minimal knowledge, the simple awareness of storms, then 99 percent of the respondents share in this knowledge. For a more sophisticated standard of knowledge 73 percent make very reasonable estimates of the maximum tidal floods experienced.[1] Ninety percent of the respondents have experienced a storm to the extent that they cite the fact of having been the present owner or manager during the passage of a storm. Over fifty percent recognize having suffered some water damage, and many more, wind damage. (See table 5-2.)

The coast dwellers interviewed exhibited an extremely high awareness of past experience, even when it is not their own. Two-thirds knew of storm hazard at the time of their original location at the study site. This would seem to arise from the distinct orientation of the respondents. In contrast to flood plain dwellers or inhabitants of zones of high seismic activity, coastal dwellers do not just happen to be there. Over half, in response to an open-ended question, suggested that it is the adjacency to the sea that has attracted them to their location. The coastal dweller attracted to the sea for recreation or commerce becomes uniquely aware of its variation. Even the seasonal residents, who only see the sea in its usually more placid moods seem to share this heightened awareness. On the coast the sea is always present, the daily variation of tide reminds one of its potential for changing its level. The use of boats, beach, and water sports, with their sensitivity to weather, provide at least some knowledge of phenomena that contributes further to this awareness.

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[1] These estimates were calculated by first asking respondents to indicate the highest known water at their location. Then the interviewer converted this statement into an elevation and this was compared with the range of tidal flooding given for each site in table 1-4. It is obvious that in the process of conversion many errors creep in and the data should only be considered as illustrative of the very high level of hazard knowledge found among coastal respondents. The knowledge of maximum flood heights by riverine flood plain residents is much inferior.

Table 5-2

Knowledge and Experience of Hazards of Respondents

	Number of Respondents	Percent
Knowledge of Hazards at Time of Location on Shore:		
No knowledge	117	33.1
Knowledge	236	66.9
Total	353	100.0
Knowledge of Hazards at Present:		
No knowledge	3	0.8
Knowledge	366	99.2
Total	369	100.0
Knowledge of Maximum Flood:		
Estimate more than 1 ft below maximum flood	76	23.0
Estimate within 1 ft of maximum flood	241	72.8
Estimate more than 1 ft above maximum flood	14	4.2
Total	331	100.0
Actual Hazard Experience		
No Experience	39	10.6
One Experience		
No damage	49	13.3
Light damage	22	6.0
Medium damage	19	5.1
Heavy damage	21	5.7
Two or More Experiences		
No damage	86	23.3
Light damage	33	8.9
Medium damage	38	10.3
Heavy damage	62	16.8
Total	369	100.0

But the realistic appreciation of what is possible by storm or tide, the universality of knowledge of the past or present, does not carry over into the future. The high awareness of past experience is diluted considerably in the second component of perception, the expectation of future hazard. Table 5-3 relates information, and table 5-4 damage experience, to future expectations of storms and damage. Despite the fact that 90 percent of the respondents experienced storms, only two-thirds expect them in the future. Only half

Table 5-3

Present Hazard Information of Coastal Respondents
and Expectations of Future Hazards
(368 Respondents)

Present Hazard Information	Expectation of Future Hazards (% of respondents)				Total
	No storms or damage expected	Storms and damage uncertain	Storms expected but no or uncertain damage	Storms and damage expected	
No knowledge	0.8	-	-	-	0.8
Knowledge	2.2	2.4	4.3	0.8	9.7
One experience	6.5	5.7	8.4	9.4	30.0
Two or more experiences	4.6	8.7	22.7	23.0	59.0
Total	14.1	16.8	35.4	33.2	99.5

Table 5-4

Present Damage Experience of Coastal Respondents
and Expectations of Future Hazards
(370 Respondents)

Present Damage Experience	Expectation of Future Hazards (% of respondents)				Total
	No storms or damage expected	Storms and damage uncertain	Storms expected but no or uncertain damage	Storms and damage expected	
None	8.4	8.4	23.2	6.5	46.5
Light	2.2	2.7	5.4	5.1	15.4
Medium	1.4	2.2	4.3	7.8	15.7
Heavy	2.2	3.5	2.7	14.0	22.4
Total	14.2	16.8	35.6	33.4	100.0

of the respondents that experienced damage in the past expect damage in the future. The link between simple awareness of the past and expectations of future events is apparently complex.

Interpretation, the link between past experience and future expectations. Our knowledge and our experience of real events in the world is personalized and even distorted as it passes through preconceived frameworks of reference related to concepts of uniqueness and repetitiveness in a process that we may call interpretation. In table 5-5 respondents have been classified by a type of content analysis based on their responses to structured and unstructured questions. The field party tried to get people to talk about storms, and it is from these verbal clues that the categories of interpretation have been somewhat subjectively derived.

Most respondents appear to interpret storms as repetitive events and many feel that the repetition is in some fashion constant. "Just the process of nature in this area for storms to come every year." "We get storms, with serious ones at about ten-year intervals." For others, storms are increasing, either by the hands of men, "They are shooting these rockets up on Wallop's Island," or as a result of perceived spatial migration of hurricane tracks, "They are running up the coast." Spatial cycles are also reversed and others perceive it as "the cycle goes from North Carolina to Florida." For these respondents storms are decreasing either in frequency or intensity.[1]

But for a fair number of respondents, storms are either unique or unknowable. "The 1962 storm was a freak." "Nature is too unpredictable." And for a very small number of respondents hazard is to be denigrated or even wished away by some semantic magic. "We never have any bad storms," "We might have a couple of hurricanes, but not a storm."

These interpretations, garnered from the spoken clues of the world within peoples' heads, do help to explain the gap between experience and future expectation.[2] For example, the coastal respondent who interprets his experience as a freak, unique event derives no future direction from his experience, and uncertainty or denial are likely future expectations. Or it is common for elderly retired couples, to feel, despite their awareness of storm hazard, a sense of personal exclusion. Storms are spaced in time sufficient that they will be granted a breathing spell, to spend their limited years in relative security.

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[1] Note that these are spatial cycles and they may be compared with temporal cycles identified in the perception of hazard by riverine floodplain dwellers.

[2] Statistically the improvement in relationship between present information and future expectation can be measured by the use of ϕ, appropriate for measuring the strength of a relationship in 4x4 contingency tables. For the relation between information and future expectation of storms and damage, $\phi = .34$. It increases to .85 in a 4x4 table in which interpretation is substituted for information.

Table 5-5

Present Interpretation of Hazards by Coastal Respondents
and Expectation of Future Hazards
(327 Respondents)

Present Interpretation of Hazards	Expectation of Future Hazards (% of respondents)				Total
	No storms or damage expected	Storms and damage uncertain	Storms expected but no or uncertain damage	Storms and damage expected	
I Respondents do not share in the common knowledge of storms	0.9	-	-	-	0.9
II Respondents share in the common knowledge of storms but:					
a) Deny the common image of storms	2.1	0.3	0.6	0.3	3.3
b) Think storms are unique	5.3	4.0	-	-	9.8
c) Think storms are repetitive and also think:					
1. They are personally excluded	3.7	0.9	0.3	-	4.9
2. Storms are decreasing in time or space	1.2	-	1.5	0.3	3.0
3. Storm trend can not be ascertained	-	2.7	16.2	12.8	31.7
4. Storms are constant in time or space	0.6	0.9	20.1	21.6	43.2
5. Storms are increasing in time or space	-	-	0.3	2.4	2.7
Total	14.3	8.8	39.0	37.4	99.5

But by no means do interpretations always lead in the obvious direction of expectations. Even for those respondents who find the repetition of storms an ordered event, the cyclical frequency might be such that the occurrence of the event reinforces a negative expectation in the future. Consider, "We get storms once in ninety years, we're not due for another." If a major storm occurs and an individual escapes serious damage, the net impact frequently is to reinforce feelings of security as at Wildwood Crest. Storms might be expected by a respondent in the future, but only as a remote depersonalized observation of his habitat with no implication of possible liability.

These interpretations also help to answer the puzzling question as to why people seemingly continue to place themselves in areas of high natural hazard by suggesting ways in which the common experience can be individually interpreted to enhance the security of expectations. In this sense, they suggest something of the way men think about natural phenomena.

Most hazards are apparently random phenomena. Those who are members of the technical-scientific community, have by their training been prepared to accept a high degree of uncertainty, at least in their scientific work, if not in their private lives. They strive with the best scientific skill to order the unknowns of natural phenomena within a framework of random probability theory, but are prepared to accept the unexplained -- to await tomorrow's knowledge.

The respondents, intelligent and articulate lay people, seem to react to uncertainty in one of two fundamentally different ways. They respond to the random occurrences of storms either by making the events knowable, finding order where none exists, identifying cycles on the basis of the sketchiest of knowledge of folk insight, and in general, striving to reduce the uncertainty of the threat of hazard by making it certain. Or conversely, they deny all knowability, accept the uniqueness of natural phenomena, throw up their hands, transferring their fates into the hands of a higher power. (See table 5-6.)

Choice of Alternative Adjustment

For both private agencies and private individuals there is widespread, although far from complete, perception of storm hazard. This perception provides, as noted, the necessary but not sufficient condition for action to reduce the toll of tidal flood damage. Awareness of alternative adjustments, proper resources to undertake them, and a set of institutional arrangements for their implementation are required for the choice between adjustments. The process of public choice is partly formalized and differs from private choice; thus each may be considered separately.

Public choice of adjustment. It may help to recall the range of adjustment described in the previous chapter. They were: loss bearing, warning and emergency action, floodproofing, protective works, and land use change and guidance. No single agency seems to choose among the entire range of adjustments for a combination that might provide for beneficial use of the shore at lowest cost to society. However, the Corps of Engineers, especially after passage of P. L. 71 which empowers it to investigate - " . . . methods of . . .

Table 5-6

Common Response to the Uncertainty of Storm Hazard

Eliminate the Hazard		Eliminate the Uncertainty	
Deny or Denigrate its Existence	Deny or Denigrate its Recurrence	Making it Determinate and Knowable	Transfer Uncertainty to a Higher Power
"We might have a couple of hurricanes, but not a storm."	"The 1962 storm is a freak."	"We get storms once in ninety years, we're not due for another."	"An Act of God, impossible to tell."
"We never have any bad storms."	"That was a freak, won't happen again."	"The cycle goes from North Carolina to Florida."	"God doesn't tell us things like that."

improving warning services, and of possible areas of preventing loss of human lives and damages to property,"[1] comes closest to having such a comprehensive policy. A recent publication of the Coastal Engineering Research Center "intended to describe in non-technical terms how the forces of the sea operate and the measures we can take to combat them," provides an authoritative statement of the present view of the Corps as to appropriate adjustments and the responsibility for their implementation.[2] This has been supplemented by a review of seventeen studies made on the study shore under the authorization of P. L. 71.

The range of choice for the Federal Government. For the Federal Government, the range of choice seems to consist of: loss bearing in areas that cannot be protected within economic feasibility, protective works where feasible, and the provision of information, mainly hurricane warnings.

The position on loss bearing is of course only implied. The Corps does not advocate that people bear losses, but it follows from the requirement that protection must show benefits in excess of costs that such an adjustment might be the cheaper one in the long run.

The Corps strongly supports effective warning nets and emergency action, but here the emphasis is upon the Weather Bureau to provide and disseminate warnings to the local communities for their action.

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[1] Public Law 71, 84th Congress, approval 15 June 1955.

[2] U.S. Army Coastal Engineering Research Center, Land Against the Sea, foreword.

Protective works are the favored adjustment of the Corps. In the words of the standard phrase of New England District reports, "the most positive means of protection consists of structures which will physically reduce or prevent the inundation of properties by tidal flood waters."[1]

Floodproofing and land use change and guidance are thought to be important methods of reducing damages "with respect to future construction" but "cannot be expected to rectify past errors."[2] But it is "the responsibility of seaside communities to provide zoning regulations so that no permanent buildings are constructed within the area of shoreline fluctuations or without adequate dune protection," and "to provide adequate building standards to minimize damages during extremely severe storms."[3]

In their attitude towards adjustments over which the Corps has no direct control, reports differ in two important aspects. In reports that recommend protective works, only perfunctory discussion is found regarding alternative means of flood damage reduction.[4] Where such works are not found feasible (in half the studies examined) lengthy discussions of damage-reduction adjustments that include warning and emergency actions, zoning, building codes, dune protection, and the preparation of maps are found. But, considerable differences are found in Corps of Engineers reports from district to district. Some districts include supplementary data designed to encourage development of evacuation procedures or to encourage further work in providing information utilizing the provisions of the floodplain information program.[5]

As part of any decision to employ protective works, there is need to consider the amount of protection. As noted, congressional approval prescribes that the benefits

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[1] U.S. Congress, Wareham and Marion, Mass. . . . Interim Hurricane Survey, House Doc. 548, 87th Congress 2nd Session, 1962, p. 54.

[2] U.S. Army Coastal Engineering Research Center, op. cit., p. 36.

[3] U.S. Army Coastal Engineering Research Center, op. cit., p. 36

[4] Some adjustments, such as building code revisions, are seemingly dismissed in advance because of local attitude: "Such measures are highly desirable but tend to meet opposition when proposed in a highly developed area where property owners and municipalities face . . . an increase in building costs due to more rigid building codes." U.S. Congress, New London, Conn. . . . An Interim Hurricane Survey, House Doc. 478, 87th Congress 2nd Session, 1962, p. 34. The implication of providing protection to communities unwilling to protect themselves is not discussed.

[5] For example: U.S. Congress, Atlantic Coast and Southern New Jersey and Delaware . . . Interim Hurricane Survey, House Doc. 38, 89th Congress 1st Session, 1965 includes a resume of Sec. 206, P.L. 86-645 Flood Control Act of 1960 and the objectives of floodplain information studies, procedures for application, etc. Another section includes a complete copy of a "A Model Hurricane Plan for a Coastal Community."

shall exceed the costs, but this criterion is not sufficient to yield an economic optimum,[1] nor is one apparently sought. Rather, the informal rule that appears from a reading of these studies is to build to the level of the Standard Project Flood or provide the maximum protection within economic feasibility.

The range of choice of state and local governments. Potentially, the range of choice of state and local governments should be greater than the Federal Government. In addition to authorizations similar to the congressional ones to provide for construction of projects, these non-Federal Governments have a set of police powers reserved to them by the Constitution.[2] One exercise of such power, found in a number of states, is the regulation of coastal structures. A second exercise of power is shown in these instances of floodplain zoning and building ordinances found in the course of the special survey. A third example is the use of health regulations on Assateague Island to delay proposed construction of summer homes in the area proposed for the National Seashore.

How one state views its range of choice can be found in the following statement from a recent report prepared for the North Carolina Department of Water Resources:

> "(1) When it is realized that hurricanes, which may strike any part of the North Carolina coast, can cause damages within a 13-month period greater than the total state tax revenue, then it becomes clear that every effort must be made to develop an effective program of damage prevention. Not only are the initial damages great, but destruction of natural resources and capital equipment paralyzes the coastal economy.
>
> (2) In broad terms the elements of a program of hurricane damage prevention appear to include adequate storm warning and disaster relief systems, physical measures to control shore erosion and to rehabilitate damaged beaches, and land use regulations designed to minimize damages.

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[1] The failure of the test of economic feasibility to provide optimal economic allocation of resources has been well documented in widely available literature. See: Otto Eckstein, Water-Resource Development, The Economics of Project Evaluation (Cambridge: Harvard University Press, 1958); Jack Hirshleifer, James De Daven, Jerome Milliman, Water Supply: Economics, Technology, and Policy (Chicago: University of Chicago Press, 1960); Roland McKean, Efficiency in Government Through Systems Analysis (New York: John Wiley and Sons, Inc., 1958); Arthur Maass, Maynard Hufschmidt, et al., Design of Water-Resource Systems (Cambridge: Harvard University Press, 1962); Maynard M. Hufschmidt, John Krutilla and Julius Margolis, Report of Panel of Consultants to the Bureau of the Budget on Standards and Criteria for Formulating and Evaluating Federal Water Resources Developments (Washington: U.S. Bureau of the Budget, 1961); W.R.D. Sewell, John Davis, A.D. Scott, and D.W. Ross, Guide to Benefit-Cost Analysis (Ottawa: Queen's Printer, 1962).

[2] Allison Dunham, "Flood Control Via the Police Power," Univ. of Pennsylvania Law Review, vol. 107 (June, 1959), pp. 1098-1132.

(3) No serious questions have been raised concerning existing warning and disaster relief measures. Federal and state programs apparently operate to general satisfaction. At the local level a program such as Dare County's shows what can be done locally.

(4) In the wake of recent destructive storms, research is still in process to identify the most effective and economical physical means of controlling shore erosion and rehabilitating damaged beaches. Its results will bear upon financing questions as well as upon a choice of physical methods.

(5) It is apparent that the task of restoring and maintaining shore protective works is beyond the capacity of local governments in the area. Continued Federal aid will undoubtedly be essential. A basic issue to be settled is the proper role of the state government in this area.

(6) Another element of a comprehensive damage prevention program lies in the application of building codes and other regulations relating to land use.

The state has moved directly in one aspect of land use regulation by enactment of legislation prohibiting unjustified damage to sand dunes along the Outer Banks. Presently the application and enforcement of this law is left to local government."[1]

This summary represents a thoughtful attempt to grapple with the definition of the proper role of the state and local government in the combination of protective works (about which it is noted much remains unknown), warning and emergency actions, and land use regulations. Unfortunately, this study is almost unique; only a similar study made in Rhode Island, provides a comprehensive state review of the range of choice.[2]

On the whole, the heavy reliance on protective structures found in Corps recommendations are matched by state and local governments with all the study shore states except one having various programs of funding protective works from state funds, or more often, sharing with the local governments, in the non-Federal portion of Federal projects.[3]

Trends in the public choice of adjustment. Some important trends might be noted in the public choice process. First and most important, the extent of Federal commitment

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[1] State of North Carolina, Department of Water Resources, Flood Damage Prevention in North Carolina, Dept. of Water Resources, 1963, pp. 94-95.

[2] Rhode Island Development Council, The Rhode Island Shore: A Regional Guide Plan Study, 1955-1970, Rhode Island Development Council, 1957.

[3] Coastal Research Notes, Oct. 1964, pp. 12-15, carries a reproduction of a review of state participation in local shore protection projects made by F. O. Diercks.

has grown over time although it is still far short of the commitment of the Federal Government to provide flood protection on rivers. The history of the expansion of commitment is linked to a now familiar pattern of crisis.[1] Public Law 71 authorizing the hurricane studies followed on the heels of the devastating hurricanes of 1954 and 1955. Public Law 87-874, which increases federal support for beach erosion control projects from one-third to one-half for public areas and up to 70 percent for public areas meeting park criteria, followed the storm of March 6-7, 1962.

Along with the increasing commitment has come greater knowledge of shore processes and the range of adjustment to hazard. The consequence of the first is a trend to greater reliance on providing artificial support for natural defenses of beach and dune. With the second has come further interest in other adjustments, but little implementation of these to date, except for the substantial improvement in the warning network.

Private choice of adjustment. The process of public adjustment is formalized to a considerable extent and it is possible therefore to study it in some detail. Reports and surveys are available that attempt to set forth the adjustments considered at individual sites and some of the thinking employed in their evaluation. These reports are prepared by individuals with a major, professional commitment to reducing tidal storms damage. It is to be expected that their range of choice will be much broader than that of a single user of the shore, for whom the process of decision-making for tidal storm damage reduction is only a small part of the welter of decisions that face his every-day existence.

The range of choice of respondents. Because one expects a restricted, perceived set of alternatives for the private users of the shore, it may help to recall the findings in the previous chapter related to actual adjustments. Every form of adjustment to hazard was found to be applied in some form by the respondents, but these applications were limited in extent and in incidence.

A similar finding holds true for the range of alternatives perceived. Alternatives for tidal storm damage reduction recognized by respondents include the entire range of such adjustments, but no single respondent perceives more than a small set of adjustments. Nor is it necessarily reasonable to expect otherwise. The range of adjustments suitable for consideration over the entire study shore may not be practicable at every site and even less so in the individual situation of each respondent. Therefore, in order to explore further the process of choice of the private users of the shore, and to allow for variation between sites, a simple differentiation of adjustments was devised between common and uncommon adjustments.

In general, the common adjustments are those described in the previous chapter that require little prior preparation and are seldom of a permanent nature. They include all the emergency actions without prior preparation. By contrast a planting of imported beach grass for dune stabilization represents a higher order of adjustment requiring not

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[1] The classic discussion of this pattern is found in Henry C. Hart, "Crises, Community and Consent in Water Politics," Law & Contemporary Problems, vol. 22 (1957), pp. 510-537.

merely expense, but a higher order of attention and concern as well. For those respondents who seek adjustments through public aid, the signing of a petition requesting the construction of a seawall would represent a common adjustment. In contrast, participation in a personal delegation to Washington seeking protection represents a higher order of action. In this way, the large variety of hazard reducing actions are categorized and the relative difficulty of pursuing them at different sites considered. For the entire sample, the alternatives perceived and adopted are identified in table 5-7.

Table 5-7

Perception and Adoption of Alternative Adjustments by Respondents
(368 Respondents)

Adjustments only Perceived	Number	Percent
No adjustments perceived	80	22.0
Common adjustments perceived	40	10.9
Uncommon adjustments perceived	4	1.1
Adjustments Perceived and Adopted		
Common adjustments perceived and adopted	159	43.2
Uncommon adjustments perceived and adopted	85	22.8
Total	368	100.0

Two-thirds adopt some minimal action, one-fourth adopt at least one uncommon adjustment, and on the other hand, one-fourth of the respondents perceive no possible adjustments. As might be reasonably expected the willingness to adopt actions, especially uncommon ones, is strongly related to the perception of hazard, and information about the past conditions and future expectations. More critical though is the motivation that stems from previous damage experience and the availability of resources to undertake uncommon adjustments. Significantly larger proportions of uncommon adjustment adopters have suffered heavy damage and possess higher incomes. (See table 5-8).

Comparison of the Perception of Riverine and Tidal Flood Hazard

The foregoing section presented a set of relevent characteristics of the perception of hazard and of the choice and adoption of adjustments. However, these data cannot by themselves provide an adequate basis for evaluation. The perception of hazard seems high, and the perception and adoption of adjustments appears widespread. But an understanding of hazard perception requires some comparison, either relative to an absolute base, or relative to other groups. No meaningful base seems to exist, but two comparisons are

Table 5-8

Relation between Adoption of Uncommon Adjustments to Hazards and Characteristics of Respondents

Characteristics of Uncommon Adopters	No. of Uncommon Adopters	Percent of Total Uncommon Adopters	Percent of Total Respondents
Expect future storm and damage	37	44.0	33.5
Suffered heavy damage	32	38.1	22.8
Income over $8,000	28	59.5	49.0
Income over $15,000	16	34.0	22.2

possible. The first has been presented; a comparison in hazard perception between shore users in the private sector and the technical experts employed by public agencies. A second comparison would be between the shore users and land users in somewhat similar hazard areas, namely riverine floodplains.

By agglomerating interviews with 216 floodplain dwellers at seven sites with varied physical situations and land use, a somewhat comparable sample to the 371 shore users is provided.[1] In both samples similar interview schedules were used. The comparative results for four major parameters of hazard and adjustment are presented in figure 5-1. Two major conclusions are easily drawn. There is clearly a higher order of hazard perception and adjustment adoption among the coastal respondents than among the floodplain dwellers, confirming an intuitive estimate of the high state of hazard awareness by the users of the shore.

A second and most interesting observation deals with the amount of variation in the same characteristic in the two samples. For example, a variety of interpretations is found in both groups but 75 percent of all coastal respondents' interpretations fall into two categories (storms are repetitive, trend cannot be ascertained or trend is constant in time or space) and their interpretations are markedly more concentrated. It previously had been felt that the amount of variation in interpretation was a function of the ambiguity of the hazard itself. If interpretation reflects the personalized view of the world superimposed on some common knowledge, to the extent that the common knowledge is ambiguous or obscure -- then the distortion of that knowledge measured by the variance of interpretation should increase. Evidence on the floodplain first suggested the hypothesis that variation of all sorts -- in knowledge and experience, interpretation, future flood experience, and the

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[1] See R. W. Kates, Hazard and Choice Perception in Flood Plain Management, Dept. of Geography Research Paper No. 78, Univ. of Chicago, Dept. of Geography, 1962, pp. 29-44; and R. W. Kates "Perceptual Regions and Regional Perception in Flood Plain Management," Papers and Proceedings of the Regional Science Association, Vol. 11, (1963), p. 219, for details.

VARIATION BETWEEN FLOODPLAIN AND COASTAL RESPONDENTS IN MAJOR HAZARD PARAMETERS

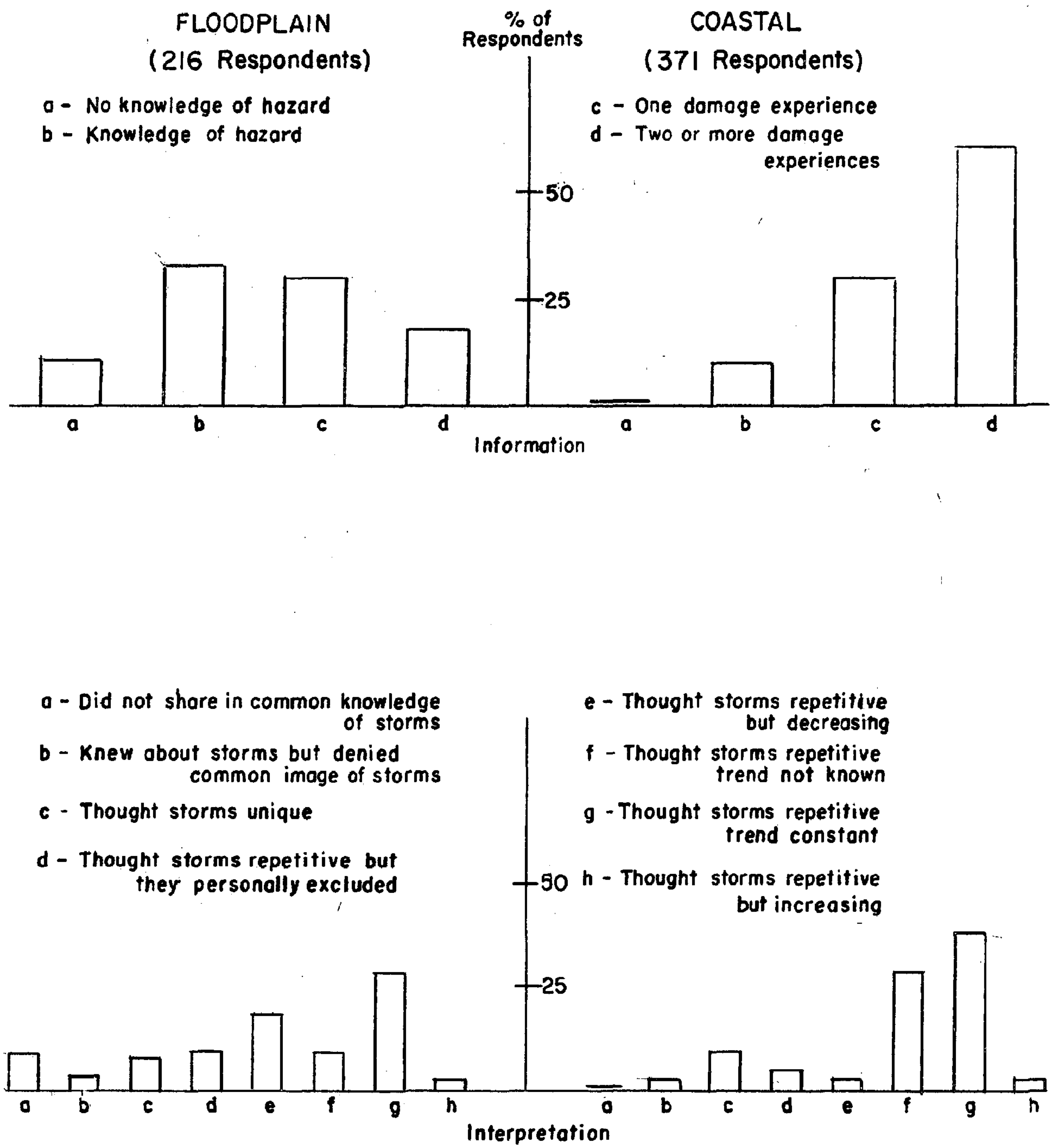

Figure 5 - I (a)

VARIATION BETWEEN FLOODPLAIN AND COASTAL RESPONDENTS IN MAJOR HAZARD PARAMETERS

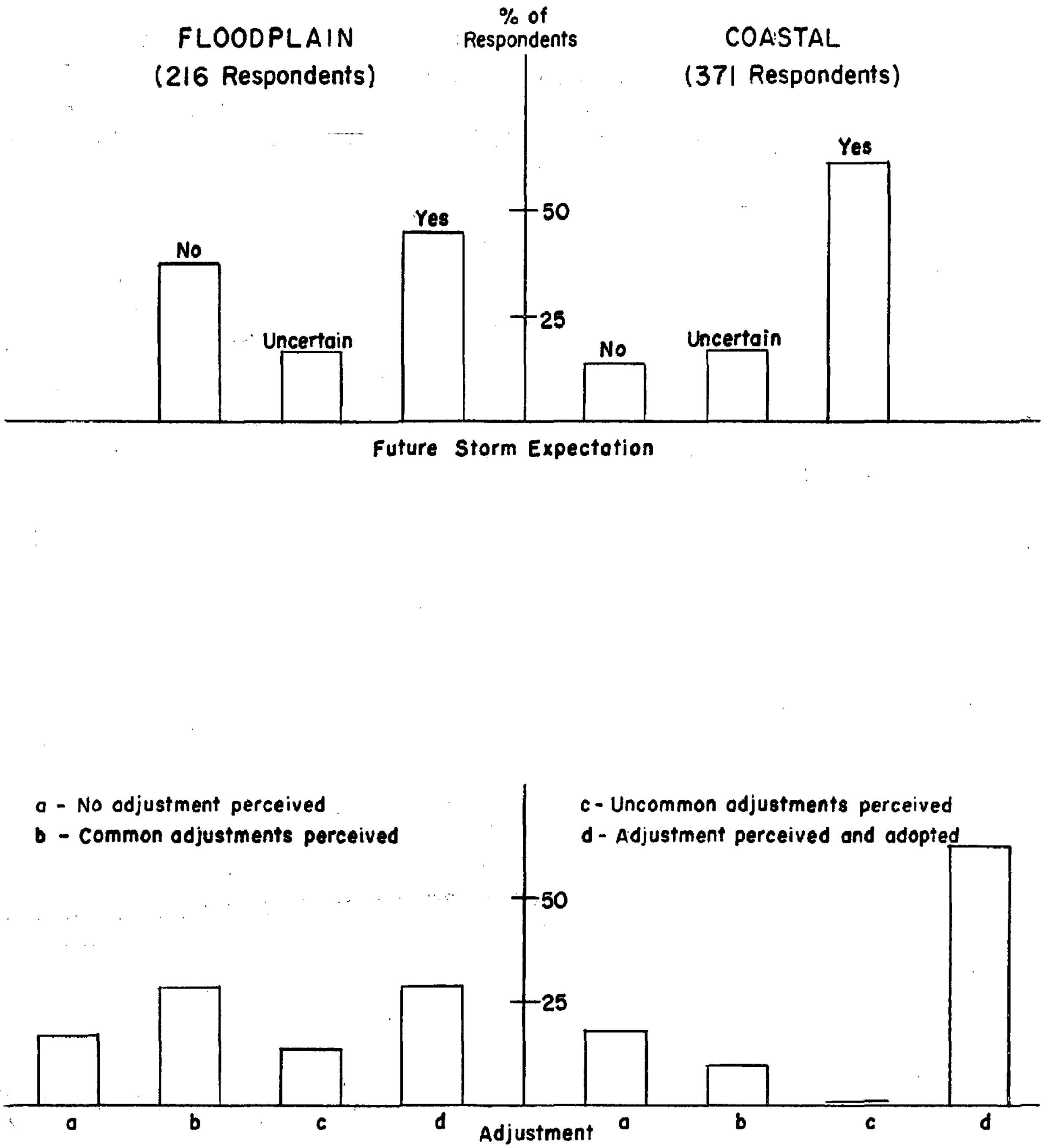

Figure 5-1 (b)

perception and adoption of hazard-reducing actions were highest in areas where floods occurred often enough to be fairly well known but not often enough to make their occurrence certain. Variation among individual perceptions fell off in areas of frequent floods or very infrequent floods. Here the meaning of the absence or presence of events seemed less confused and liable to variation in interpretation. This variance of behavior found in interpretation is higher for floodplain respondents in all the other hazard parameters as well. As suggested, this seems to be a function of the ambiguity of the hazard and the greater variation in hazard settings at the seven floodplain sites as compared to the relatively greater consistency in hazard found along the shores of Megalopolis. As an index of this hazard differential, the weighted mean recurrence of floods for the 216 floodplain respondents was about four every ten years and a similar recurrence of damage-producing storms for coastal respondents was nine every ten years.

Still another comparison between coastal and floodplain respondents is the adoption of adjustments. In previous study of riverine floodplains a classification similar to the one employed in this study showed evidence of scaling, i. e., those that adopted uncommon adjustments also adopted common adjustments and those that adopted any adjustment, generally perceived an uncommon adjustment.[1] In other words adopters appeared to choose from a wider range of alternatives than non-adopters. This does not seem to be the case with the coastal respondents. Two-thirds of all respondents adopt some minimal action but of the 159 common adopters only four perceived some uncommon alternative which they did not act upon. The discrepancy between this study and the previous one might arise from the classification employed, the sampling and interview techniques, or may represent a genuine difference. The very high perception of hazard by coastal dwellers leads to a very high rate of adoption of alternatives. If they are perceived, they are acted upon.

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[1] Robert W. Kates, Hazard and Choice Perception . . . p 125.

CHAPTER VI

THE HUMAN USE OF THE SHORE

The 1300 miles of outer shore studied in this report provides recreation for many of the 40 million inhabitants of Megalopolis. For thousands of them, it provides home and livelihood as well. Enough structures to house a city the size of Boston line the shore. Although protected by almost three hundred miles of engineering works, average annual damages from tidal flooding might be estimated conservatively at $25 million. What appear to be the major trends in use of the shore and what is an appropriate strategy for human occupance of this boundary between land and sea?

The Village Shore: Between Two Worlds

The village shore is an occupance type in transition between two very different economies, one based on the food resources, the other based on the amenity resources, of the sea. The former, despite the coloration lent by romantic nostalgia, is at best a difficult livelihood, and the only sizable numbers of poor people found along the study shore were at the village sites. Fishing was not the only source of income, and agriculture was frequently found close to the village shore possibly attracted originally by the convenient cutting of salt hay in the tidal marshes. Today, the only sizable amount of agricultural land encountered in the intensive study was along the village shore. (See table 6-1.)

Table 6-1

Land Use by Occupance Type and Hazard Zone

Land Use	Zone B: Tidal - 10 Feet			Zone C: 10 Feet - 20 Feet		
	Percent of Acreage Found in			Percent of Acreage Found in		
	Village Shore	Urban Shore	Summer Shore	Village Shore	Urban Shore	Summer Shore
Industrial	0.5	3.9	1.1	0.0	16.4	0.0
Commercial	1.4	1.3	5.2	1.8	13.4	6.6
Public	0.5	3.9	4.5	0.0	7.6	0.6
Recreation	5.1	24.7	19.2	5.5	10.5	5.7
Residential	35.6	53.2	19.6	27.6	37.4	37.9
Agriculture	1.8	0.0	2.1	11.6	0.0	4.4
Undeveloped	55.1	13.0	48.2	53.4	14.6	44.8
Total	100.00	100.0	99.9	99.9	99.9	100.0

The amenity resources attract a summer visitor who is different from the permanent resident of the village, and with tastes and desires frequently alien to the host community. Each of the four sites studied are in different stages of transition between a food resource-based and amenity resource-based economy and they suggest varied directions towards which the village shore might move. Significant findings for each site are summarized in table 6-2.

In all except Chincoteague, fishing continues to decline to minor proportions, but the degree that tourism flourishes varies. Wellfleet appears most successful, a tasteful transition preserves much of the favor of the original settlement and adds to the attraction of the area. Villas represents another potential direction providing a low-cost site for vacation or retirement. Point Judith suggests a major opportunity to use the valuable small harbors of the village shore for small craft, with marina-type services and sport-fishing replacing commercial fishing. A major growth opportunity is found on Chincoteague especially if the road connecting the Maryland end of Assateague Island is built. Here the community might strengthen its economy with the help of an outside infusion of capital and tasteful direction.

The direction of the transition of the village shore is important for understanding the nature of future damage potential. For in a real sense, the traditional village represents a long-term human adjustment to natural hazards in the course of its evolution. Thus the hazard potential of the village shore is quite moderate today, but it could change for the worse if, in the course of transition to a recreational economy location decisions similar to those made on the summer shore become common.

The Urban Shore: The Economics of Protection

The use of the urban shore differs markedly from the use of the village and summer shore (see table 6-3). Almost all of the land is built up and agriculture, of course, is nonexistent. Most of the industrial acreage, as expected, is found on the urban shore. Not initially anticipated were the relatively large amounts of recreational land use found on the shore in urban areas. This arises from the formal character of urban recreation, usually set aside as public parks and beaches. The far more extensive recreation area on the summer shore may be in the form of commercial motels or, most commonly, private beach residences.

Change in land use will come, in the main, from programs of renewal, both public and private, and these opportunities for damage reduction should be vigorously pressed. The substantial construction found on the urban shore makes floodproofing and the use of rigorous building codes for controlling new building and remodeling most feasible. But the major outlook for substantial damage-abatement comes from the construction of protective works. Thus the problem of the urban shore is essentially one of dealing with the economics of protection.

Table 6-2

Village Shore: Summary of Study Site Data

Study Site	Past Growth and Development	Relative Storm Frequency	Past Storm Damage	Perception of Hazard	Adoption of Adjustments	Prognosis
1. Pt. Judith	Slow growth of recreation as fish and agriculture decline.	High	Heavy	High	Wide range	Continued slow growth directed away from hazard area above 10-foot contour.
2. Wellfleet	Moderate growth of recreation, as fishing declines. Village atmosphere persists.	High	Moderate	Moderate	Few	Rapid growth expected with development of National Seashore. Large growth of damage potential unlikely.
3. Villas	Steady growth of recreation, as fishing declines.	Low	Low	Low	Few	Continued slow growth by marshland reclamation. No rapid rise in damage potential.
4. Chincoteague	Slow growth of recreation, as fishing remains important.	Low	Heavy	Moderate	Moderate range	Rapid growth possible at uncertain future date. Big increase in damage potential also possible.

Table 6-2

Urban Shore: Summary of Study Site Data

Study Site	Past Growth and Development	Relative Storm Frequency	Past Storm Damage
5. Lynn-Nahant	Steady intensification of densely developed urban shore.	Moderate	Low
6. Fairfield	Slow growth of urban residential property.	Moderate	Heavy

Study Site	Perception of Hazard	Adoption of Adjustments	Prognosis
5. Lynn-Nahant	Low	Moderate	Change contingent upon urban renewal projects. Further increase in damage potential unlikely.
6. Fairfield	Low	Moderate	Public protection rejected. Slow increase of damage potential.

However, the economics of protection need to be pursued further than the question presently asked by the Corps -- namely, do the benefits exceed the costs? The apparent emphasis on building for the standard project hurricane does not insure an economic optimum, although it does lead to the construction of substantial engineering structures. Moreover, all along the study shore there is substantial opposition to recommended works.[1]

Much of this disquietude arises from the suspicion that present benefit-cost analysis does not weight sufficiently the loss of benefits arising from destruction of amenity values, changing the ecology of esturine waters, increasing the problems of small-boat navigation, and the like. Until such time as field-level economic analysis appears more able or ready to cope with these external effects of engineering structures, one powerful instrument for improved decision-making may simply be local willingness to participate in sharing the substantial expenditures.

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[1] The attitudes discussed in Chapter IV are symptomatic of this, as is the more recent opposition voiced against the hurricane barrier at Narragansett Bay and the proposed protection for the North Shore of Long Island.

The urban shore by definition is built-up, reflecting substantial fixed investment. The opportunities for reducing damage would seem to lie in the use of a broad range of alternatives, subjected to a stringent analysis that recognizes the many negative effects of artificial control of the shore, and that insures local public concern by requiring large financial commitments from local interests.

Summer Shore: The Amenities of Sun, Sand, and Sea

The summer shore is the dominant form of occupance on the shores of Megalopolis. The future development of the summer shores is relatively simple to forecast. Except for areas earmarked for preservation by public action, the summer shore will cover all the barrier bars with a thin line of closely spaced housing, will fill much of the tidal marshes with marina-type subdivision, and will dot the bluffs with dispersed housing. For part of the New Jersey shore this barrier bar and bluff development is completed or even going through cycles of renewal, and subdivision of the lagoons is being vigorously pressed. As one goes south, or north, extensive areas of development are still available and this is reflected in the forecast for an increase in damage potential for five of the eight summer shore sites summarized in table 6-4. The disturbing aspects of this prognosis are underlined by the findings, in Chapter III, of the high vulnerability to storm hazard of the northern and southern margins of the study shore.

The summer shore poses a unique challenge to resource management. The major value of the summer shore is adjacency to the natural attractions of sun, sand, and sea. But the very desire for adjacency to the shore also makes conventional protection costly and impractical. Only one of the seventeen Interim Hurricane Studies recommended protection for a barrier bar area of the summer shore. Hazard reduction must come primarily from the nonstructural adjustments or from stiffening the natural defenses of beach and dune. A second challenge to resource management results from the present distribution of access to the amenities of sand and sea. Should the pleasures of the summer shore be reserved for the farsighted or the fortunate or should public policy consciously strive for a more equitable distribution of access to these amenities?

The Empty Shore: The Wilderness Preserve of Megalopolis

Part of the empty shore is in one sense the wilderness analogue of western America. Here, on the very shores of the most intense urban development in the world, elementary natural processes of birth, death, and renewal take place undisturbed by man with each return of the tide, change of the season, shift in climate, or passage of geologic time.

Of the four major opportunities for preservation of the empty shore foreseen by the National Park Service in 1955, three (or their equivalent) have been or will be shortly realized in the form of Cape Cod, Fire Island, and Assateague Island National Seashores.[1]

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[1] These were the Great Beach, Mass., Shinnecock Inlet and Fire Island, New York, and Parramore Island, Virginia. National Park Service, Seashore Recreation Area Survey, Washington, 1955.

Table 6-4

Summer Shore: Summary of Study Site Data

Study Site	Past Growth and Development	Relative Storm Frequency	Past Storm Damage	Perception of Hazard	Adoption of Adjustments	Prognosis
7. Hampton Beach	Rapid growth of residential property.	High	Moderate	Low	Moderate	Further expansion into marshland areas probable, with associated growth of damage potential.
8. Montauk	Slow growth of recreation	Moderate	Low	Moderate	Few	Rapid growth possible at uncertain future time. Big increase in damage potential unlikely.
9. Sandy Hook	Moderate rate of growth in past 20 years, now fully developed.	Moderate	Heavy	High	Wide range	Further growth limited to intensification of development. Rapid increase in damage potential unlikely.
10. Cape May	Steady growth by intensification of existing development.	Low	Heavy	Moderate	Moderate	Change contingent upon urban renewal projects. Rapid increase of damage potential unlikely.
11. Wildwood Crest	Rapid growth of recreation and associated commercial development	Low	Moderate	Low	Few	Continued rapid development and growth of damage potential.
12. Dennis	Very rapid growth of recreation and summer residential property.	High	Moderate	Moderate	Few	Continued rapid growth and creation of new damage potential.
13. Nags Head	Rapid growth of recreation and summer residential property.	Moderate	Heavy	High	Wide range	Continued rapid growth and creation of new damage potential.
14. Bethany Beach	Rapid growth of recreation and summer residential property.	Low	Heavy	Moderate	Wide range	Continued rapid growth and creation of new damage potential.

(See table 6-5.) But much empty shore remains. The estimate made earlier in this report was that only 21 percent of the shore frontage had been developed by 1960. The challenge is to perserve and to make accessible many of the smaller, less grandiose sections of empty shore, which by default might pass into summer shore precisely when society is showing a clear and high valuation for nondevelopment or limited development in the political marketplace.[1]

Table 6-5

Empty Shore: Summary of Study Site Data

Study Site	Past Growth and Development	Relative Storm Frequency	Past Storm Damage
15. Assateague	Wildlife refuge partly converted to recreation area	Low	Low

Study Site	Perception of Hazard	Adoption of Adjustments	Prognosis
15. Assateague	No residents	Not applicable	To be preserved as open space but increased recreational use likely.

Process, People, and Policy: A Strategy for Human Use of the Shore

The shores of Megalopolis provide the meeting ground for two major systems -- man and nature. The former is characterized by processes and patterns of economic activity, urbanization, and civilization, on scales unparalleled in human history. The latter, involves the complex interaction of the oceans of air and water upon the land. Meeting at the shore, these systems create unique forms of settlement, opportunities for respite and relaxation and increasingly important but still peripheral, economic values. An understanding of the processes of the major systems and their relation to the people of the shore, seems fundamental to any prescriptions for policy.

Process. The authors sense that the boundary of land, sea, and water is not merely the joining of three sub-systems but an important research frontier as well.

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[1] For example, in contrast to opposition to the hurricane barrier, Rhode Island residents voted 2 to 1 for the expenditure of $5 million dollars to develop seven new state parks, four of them on the shores of Narragansett Bay. Personal communication from Lewis M. Alexander, December 22, 1964.

Everywhere this study turned, evidence of human ignorance of the system was uncovered, much of it painfully revealed in errors of yesteryear. At the same time, there is considerable evidence of increased appreciation of the complexity of the natural processes at work on the shore. Effort and energy commensurate with both the problem and the opportunities for knowledge are forthcoming.

The study of natural process per se has not been the task of this study; rather the interrelation between the natural and human systems. In that light, it seems to the authors that there are four critical gaps in our knowledge of natural process that directly affect a strategy for use of the shore:

1. Knowledge of the transport of material along the shore is a most pressing need. Where does the sand come from and where is it going? Inadequate knowledge of this sort is evidenced by the failure of some protective works, the unexpected adverse effects from others, and the costly maintenance, beach nourishment, dredging, and artificial transport required in many of the successful efforts. It would seem desirable to construct materiel balances, inflows and outflows, for the entire shore.

2. A second pressing question is related to the dramatic increase in damaging storms discussed in the chapter on climatology. Rational use of the shore requires reasonable estimates of the probability of inundation and such estimates are not available. Moreover, frequency estimation of climatological phenomena involves a basic assumption of the essential stability of the underlying climatic conditions, an assumption requiring further investigation since there is present evidence of an increase and intensification of storm systems.

3. A third area, and one that will increase in importance deals with the tidal marshes. The effects of filling of marshes need further study, both in relation to marsh ecology and to the movement of material in and out of the estuary and its effect on shellfish and fish life in the estuary. A most pressing need is for a scientific base for setting elevations and conditions to be met in permitting marsh filling.

4. Finally, further study of the impact of surges on the shore, the effect of differential topography on run-up, and the stability of dune forms subject to repeated inundation is required. One goal of such study should be relatively simple methods of routing surges overland in order to assist in understanding the amount and frequency of hazard.

Despite the shortcomings of knowledge of natural processes, the natural system is more regular than the system of spatial interaction that has fostered the development of the shore. However, the broad outlines of the human system are clear and can be described. The initial advantage of coastal location is manifest today in the great port cities on the shores of Megalopolis. The nineteenth century saw a decline in many of the smaller, viable settlements found on the outer shore, a decline marked by the exhaustion of marine resources and the need of the marine industry for larger harbors. The remnants of these communities are found today in the village shore. Concurrent with the decline of a coastal-based economy has been the rise of recreational activity along the shore. Recreation fosters new forms of settlement along the shore and patterns of recreational occupance seem to follow rules different from the more work-oriented activity.[1]

Trends relevant to this recreational growth can be briefly summarized. Recreation activities are growing faster than population and increases in income. Growth rates of development of the shore and the coastal counties exceeds the rate of Megalopolitan growth and the highest rates (although still the lowest densities of development) are found in the zones of highest hazard. Associated with recreational development that places a very high premium on adjacency to water are two land-using practices that exacerbate natural hazard; inadequate filling of tidal marshes, and the leveling of sand dunes. Thus, unchecked, the rate of growth of recreational activity and the land use practices encouraged in private recreational development sets in motion a process leading to growth in damage potential considerably higher than the general growth of the nation and its economy.

People. The process of recreational development of the shore presented in the foregoing sketch has consequences for the character and attitudes of the shore population. There are in fact two populations reflected in the transition of the village shore: a population of fishermen, seasonal workers, and older persons, with incomes considerably below

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[1] A major attempt was made to develop empirical relations between the amount and growth of development along the study shore as a function of a set of independent variables representing natural conditions, historical development, regional growth, accessibility, and public use using a step-wise multiple regression approach. The density and proportion of frontage developed, as well as the growth or decline between 1940-60 and 1950-60, for the sixty-five sample areas were compared with a set of appropriate variables drawn from the following list: 1940 structures per acre, 1940 ocean frontage developed, water temperature, presence of developable sand beach, storms 1935-64, density of dwelling units in county, growth or decline of dwelling units in county, distance to town of 50,000 population or greater, and distance of town of 1,000,000 population or greater. That the findings were essentially negative, except for the expected relationship that highly developed places stayed developed, reflects in part the special nature of recreational land use.

For example in a yet unfinished dissertation study by Richard Hecock of beach use on Cape Cod, there is ample evidence that people do not tend to minimize their travel distance to the shore. On the other hand, once located on the shore, the friction of distance is very high and they tend to go to beaches located nearby. This same trend was observed in the five hundred beach user interviews made as part of this study. One explanation is that recreational travel has its own pleasurable value, evidenced by the large amount of pleasure driving. But whatever the explanation, it is obvious that the process of growth and development of shore communities is not to be explained by simple indicators of accessibility or natural conditions.

the average -- and a much larger group of summer people with education and incomes considerably higher than the population at large.

For both groups it has been shown that their adjacency to the sea has led to a relatively high perception of the risks of locating along the shore: knowledge of storms was universal and knowledge of the highest tides of record was impressive. There is also a high acceptance of hazard. For the first group it arises out of their long familiarity with the sea, and in a sense their adjustment to it. For the summer visitor it seems to arise in part from his seasonal use of the shore, and in part from the luxury aspects of recreational consumption. The view and proximity of the shore is desired; if nature is to add on a surcharge, that is part of the price to be paid. With the acceptance of the hazard is also evidenced a willingness to reduce it or ameliorate it, but not to the point that the values of sun, sea, and sand are substantially diminished.

Policy. There are numerous policy implications raised by the findings of this study. Several proposals reflect the personal views of the authors that arise from their concern with problems of natural hazard and the use of the shore. In this section, a set of implications and, in some cases, frank prescriptions for public policy are made under three levels of government: federal, state, and local community. To place these in proper perspective it is appropriate to begin by summarizing some of the personal views of the authors as to the elements in a strategy for the human use of the shore.

The proper use of the shore. The shore has a unique character and serves a special function for the population of Megalopolis. In both its natural state, and developed for recreation, the shore provides opportunities for leisure and refreshment for which there are no alternatives within easy reach of the region. The provision for a wide variety of shore recreational activities is a proper use of the shore and should be assisted by public policies.

At the same time, there are still many and varied uses of the shore not directly connected with recreation. A useful classification of the uses of the shore might be the following:

1. Coast-based. These are industrial, commercial, or recreational enterprises that require direct access to the shore (e.g. in the form of docks, pump houses, etc.) or to the shore-using public (e.g. in the form of bath houses, marinas, etc.).

2. Coast-oriented. These are enterprises or residences found along the coast because their products or services are related to the use of the shore. These include motels catering to recreationists, stores selling beach apparel, or fish-packing plants.

3. Footloose. These are enterprises or residences for which coastal location is coincidental to their major purpose.

Within the framework of this classification, it would appear proper for only coast-based structures to be found in high hazard zones. Coast-oriented structures are properly located near the shore but need not be in hazard areas, and for footloose structures, coastal location may even represent some misallocation of resources.

The proper set of adjustments. There is no best adjustment to storm hazard, but in general some combination of the range of adjustments available can provide opportunities to society to use the shore at lowest cost. Thus proper policies are those that move towards a wider consideration of adjustments.

As there is no best adjustment in general, neither is there a favored tool of coastal engineering. The physical features of the shore are too varied to reject out-of-hand any type of protective works. But clearly those defenses against the sea that are in harmony with natural processes have greater chances of success and are likely to be low cost solutions to problems in the long run.

The proper role of government. With the exception of a few villages inhabited by retired couples or impoverished fishermen, coastal users are well educated and well-to-do. They have come to the shore to share the constant attractions found at the interface of land and sea or to serve and profit by those who are so attracted. They are by and large, knowing and well-informed about the broad outlines of the hazard they face, and as to the details, the scientific-technical community is not much better off. A high proportion of coastal dwellers adopt minimal actions to reduce their hazard, but have chosen, on occasion, constant or even greater levels of hazard rather than reduce their seaward amenities. In such a situation it is only by a vast extension of the concept of the welfare state that it would appear to be a function of the Federal government to protect private property along the coast.

Conversely, it would seem to be the very proper function of government to discourage the increase in hazard potential due to ignorance and lack of knowledge or when the increase in hazard potential will cause harm to others and encourage irrational demands on public agencies.

Federal Policy Implications

Since 1955, the effectiveness and comprehensiveness of Federal programs for reducing coastal storm damage appear to be increasing. Substantial areas of empty shore have been preserved. New opportunities for storm damage reduction through purchase of recreational land will become possible with Federal grants to the states under the Land and Water Conservation Act. The warning system, especially as related to tropical disturbances, appears to be considerably improved. A more knowledgeable and thoughtful appraisal of protective works has emerged from the research of the Corps of Engineers with major future emphasis on the conservation of sand and the maintenance of the natural defenses of beach and dune. Interim Hurricane Survey Reports reflect the beginnings of a comprehensive approach to storm-damage reduction, although a disturbing dichotomy between protective works and alternative adjustments still persists.

In contrast with the improvement of Federal effort, each new crisis of damage brings new pressures for an increase in commitment to protect the users of the shore. Such pressures, fed both by the intensification of use of the shore and the apparent short term increase in damage-producing storms, will increase. It thus seems important to continue with damage reduction programs and create, as well, a climate whereby storm damage might be placed in proper perspective. To this end, the following suggestions are offered.

Information and research programs. No other level of government has the capability for disseminating accurate information and for undertaking or encouraging needed research than the Federal agencies with shore-oriented missions. In this respect, while part of the critical research needs noted in a previous section might be carried out within the internal capability of these agencies, other aspects will require the use of competent investigators wherever they may be found. It would also be a wasteful procedure to neglect wide dissemination of information, much of it already in the files of the Corps of Engineers, Coast and Geodetic Survey, Geological Survey, and Weather Bureau but not in proper form for use by lay people.

Specifically, the information collected for the Interim Hurricane Surveys should not require much additional work to be developed into floodplain information reports similar to those issued under Section 206 of the Flood Control Act of 1960. It would seem logical to request of Congress funds for that purpose as being in the spirit if not the letter of P. L. 71. A requirement that coastal communities must apply for such information would seem self-defeating. It is precisely in those communities where present development is limited, but the possible increase in damage potential is considerable, that local government is weak and vacillating and unlikely to make formal requests for information.

Comprehensive damage-reduction programs. To improve the process of choice of alternatives, several improvements in the delineation and evaluation of alternatives seem possible.

The first required action is to make loss-bearing respectable. Loss bearing is and will continue to be a minimum cost solution for the use of the shore in many areas. Although this is implicitly recognized, it is seldom explicitly set forth. But there is much to gain through encouraging public understanding that bearing losses is a legitimate way to pay nature's rent for use of the shore. It is neither a confession of engineering incompetence nor a failure of public responsibility to make clear that for much of the barrier-bar portion of the summer shore, continued loss bearing by private individuals may be the cheapest way they and society can obtain the use of the shore.

Secondly, a comprehensive damage reduction program should not have favored solutions. The present predilection for constructing protective works, and where feasible to the level of the standard project hurricane, leads to an unfortunate choice situation. In all of the eight hurricane reports reviewed making favorable recommendations for protective structures, other alternatives tend to be dealt with in denigrating terms. But there is no guarantee that, even if structures built to maximum height are desirable, they will be acceptable to the communities concerned. Thus, communities seem to be offered only two choices, build the protective works or bear losses, where in actuality a variety of damage reduction programs exist.

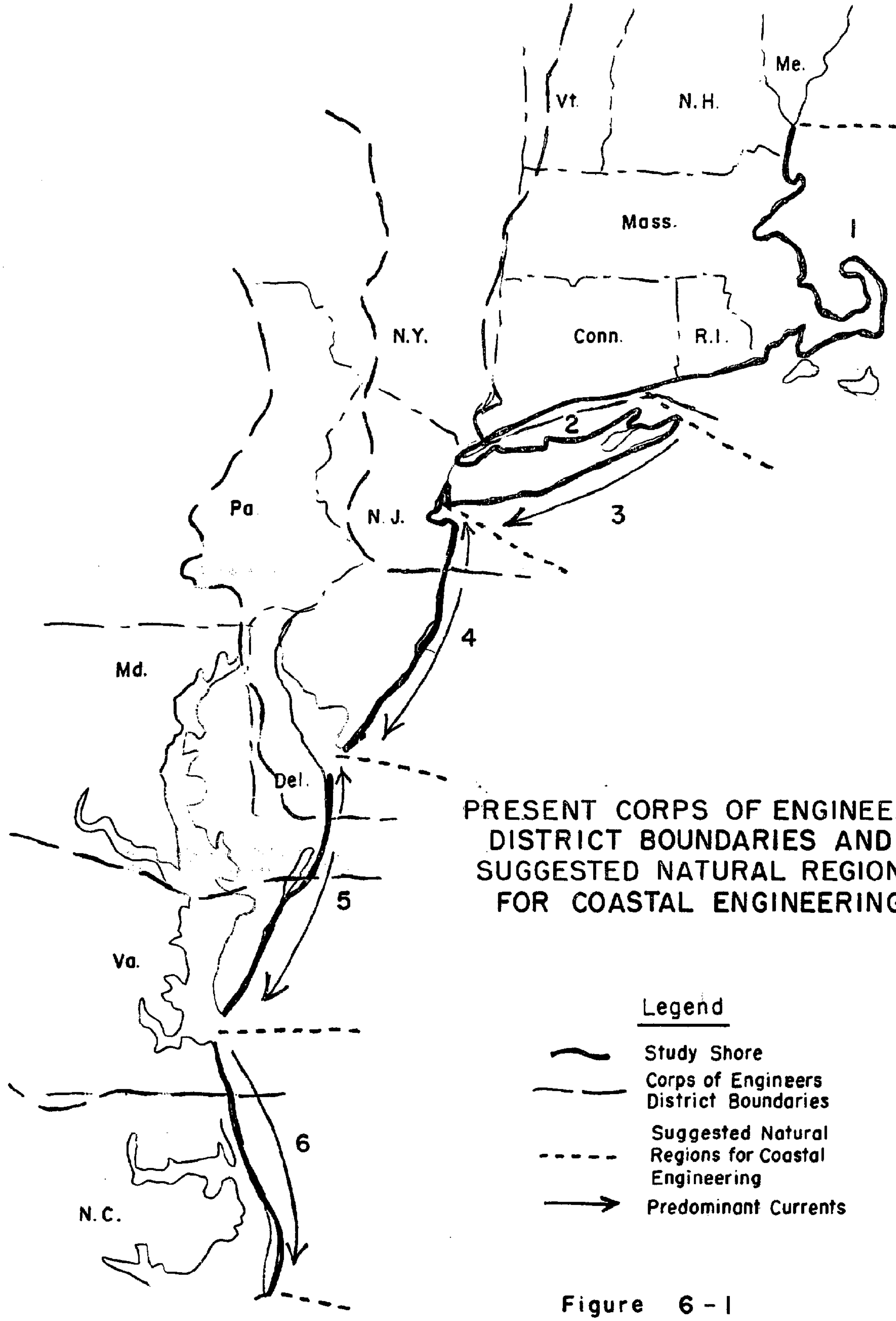
Third, the planning for protection should be in accord with natural processes where possible, much as river basins have become standard in water resource development. Unfortunately for the shore, the Corps recognizes this and district office responsibility generally follows watershed boundaries. These watershed boundaries are not in accord with the critical lateral movement of materials along the shore. This is shown in figure 6-1. Table 6-6 that accompanies the figure suggests a set of natural regions for planning shore protection and preservation. It is not known whether the district administrative boundaries contributed to the fragmented protection process that characterizes much earlier planning, but adoption of more comprehensive planning regions seems advisable.

Table 6-6

Suggested Natural Regions for Coastal Engineering

1.	New England	A complex area with currents from several directions but predominately from north to south. All headlands are source regions.
2.	Long Island Sound	Characterized by an internal circular current system.
3.	South shore of Long Island	Wave erosion takes place at Montauk Point. Main current moves from east to west.
4.	New Jersey	Wave erosion takes place from Atlantic Highlands to Asbury Park. Small current moves material north to Sandy Hook. Main current moves material south.
5.	Delmarva Peninsula	Wave erosion takes place between Rehoboth Beach and Bethany Beach. Small current moves material north toward Cape Henlopen. Main current moves material south.
6.	North shore of Cape Hatteras	Source area near Virginia Beach. Small current moves material north toward Cape Henry. Main current moves material south toward Cape Hatteras.
7.	South shore of Cape Hatteras	Bulk of the material moves north from source region in South Carolina and Georgia.

Source for ocean currents - Dean F. Bumpus and Louis M. Lauzier, Serial Atlas of the Marine Environment, Folio 7, American Geographical Society, 1965.



PRESENT CORPS OF ENGINEERS DISTRICT BOUNDARIES AND SUGGESTED NATURAL REGIONS FOR COASTAL ENGINEERING

Figure 6 - 1

Public access to the shore. Fortunately, the public goals of increased opportunities for recreation and the reduction of damage potential are generally harmonious. Much more work needs to be done in developing programs that combine damage reduction and increased recreation especially through purchase of land. Much of this is more appropriate at other levels of government, but Federal encouragement financially and otherwise is needed. In connection with the relation between public recreation and damage reduction, peripheral observations made by the field parties in the course of study are relevant.

Everywhere, and in many guises, the public right of access to publicly owned shore is abrogated by private or excessively parochial local governments. In a few instances, this takes the form of actual misuse of the land but more often it is a de facto appropriation by a variety of devices including the following: failure to inform of rights of access, erection of trespassing or private property signs, closing of streets or paths to be the beach, failure to provide passage across sea walls, or prohibitions on traffic and parking.

The provision for open public use is a clear requirement for Federal participation in many protection and preservation projects. Provisions should be made for the inspection to insure the maintenance of these rights and Congress should provide funds to use projection projects as a lever to extend public access to the shore. At a minimum, signs should be posted informing the public of their rights to open use, when such rights are not self-evident.

State Policy Implications

In reviewing the entire gamut of actions that might be taken to reduce storm damages, it appears that the major opportunities lie with the respective coastal states and for the most part, these have been sadly neglected. The states have reserved to themselves a wide variety of police powers. Each has distinctive laws and even traditions relevant to the use of the shore which makes Federal legislation, even where proper, somewhat complicated. And the states have a vigor and financial base not often found in most small shore front communities. A proper state program, blending regulation, financial encouragement, and planning assistance can be a most effective approach to reducing tidal flood damage.

All the coastal states have some program aimed at damage reduction. Almost all provide matching funds to local communities for protection. Many have ambitious programs for purchase of open space that may be artfully employed to reduce damage potential. And at least two have attempted to assess the elements of a comprehensive damage reduction program. But there seem to be three neglected areas of improvement.

Planning assistance. All the states in the coastal region has provisions for planning assistance in local communities and some on the state level as well. Some states employ personnel to work with communities directly, others merely act as certifying agents for contracts with private consultants. Table 6-7 presents the general status of relevant

Table 6-7

Summary of Selected State Planning Activities and Legislation
for State Planning and Local Land Use Controls

	State has State planning legislation?		State has agency actively concerned with over-all State planning?		State Planning Agency is concerned with flood damage prevention?		State provides local planning assistance?		State has local zoning enabling legislation?				State has local subdivision control enabling legislation?			
									For Cities		For Counties		For Cities		For Counties	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Connecticut	●		●		●		●		●		Θ		●		Θ	
Delaware	●			●		●	●		●		O			●	●	
Maryland	●		●			●	●		●		●		●			●
Massachusetts	●		●			●	●		●			●	●			●
New Hampshire	●			●		●	●		●			●	●			●
New Jersey	●		●		●		●		●			●	●			●
New York	●			●		●	●		●			●	●			●
North Carolina	●			●		●	●		●		O		●			●
Rhode Island	●		●		●		●		●		Θ		●		Θ	
Virginia	●			●		●	●		●		●		●		●	

Legend: O certain classes of cities or counties; Θ no provision for county regulations but boroughs (Alaska), parishes (Louisiana), or towns (Connecticut and Rhode Island) may adopt regulations.

Source: H. F. Morse, Role of the States in Guiding Land Use in Flood Plains, p. 27.

planning programs in the coastal states. Tennessee has the most extensive program of planning assistance to communities for reducing riverine flood damage programs and their actions might provide a model for other coastal states.[1]

Regulation. Three types of regulations seem suited for adoption on the state level. These should be regulations to control the filling of marshland, preservation of dunes, and provision within the state building codes for hurricane-resistant construction and minimum elevations in coastal areas. North Carolina, which has adopted state legislation to protect the Outer Banks, leaves enforcement to the local communities. However, all three areas; marshland filling, dune preservation, and specialized building codes require services for enforcement usually not found on the local government level. The widespread use and acceptance of a state fire marshal might be duplicated in this need for specialized service.

Public access of the shore. The ownership of tidelands varies from state to state. (See table 6-8.) In six coastal states tidelands are held in public ownership from the mean

Table 6-8

Tidelands Ownership and Access, Coastal States

State	Upland Boundary of State Ownership		Extent of Use			Rights of Upland Owner	
	High water	Low water	Extensive	Moderate	Slight or none	Prior claim of purchase	Accretion and reclamation
Conneticut	X	....	(1/)	(1/)	....	....	X
Delaware	X	....	X	....	....	....	X
Maryland	....	X	....	....	X	....	....
Massachusetts	....	X	....	X	....	....	....
New Hampshire	....	X	X	....	....	....	X
New Jersey	X	....	X	....	....	X	....
New York	X	....	....	....	X	X	....
North Carolina	X	....	....	X	....	....	....
Rhode Island	X	....	X	....	....	....	....
Virginia	....	X	....	....	X	....	....

1/ Not available.
Source: Shoreline Recreation Resources of the United States, ORRRC Report No. 4, p. 20

[1] A comprehensive guide for state activity is found in H. F. Morse, Role of the States in Guiding Land Use in Flood Plains, Georgia Inst. of Tech. Eng. Exp. Station Report 38 (Atlanta, 1962) and its accompanying bibliography.

high water line to the sea. In these states, vigorous programs for access could provide almost the entire shore in public trust. Experimentation might be made with programs to purchase narrow strips of land paralleling the shore. Such a strip, possibly ten yards wide, does not have to interfere seriously with private property rights, and yet it could provide both public access to the shore and an extended buffer area that could be prepared to absorb the energy of a storm surge. In all states there are a considerable number of small pockets of empty shore. Imaginative use of funds provided by the HHFA open space program and the Land and Water Conservation Act might preserve and make accessible these parcels.

Local Government Policy Implications

Many of the foregoing policy suggestions may be applicable on the level of local government as well as higher levels. There is some evidence of the desire of many communities for a stable, orderly pattern of development. But of all the actions best suited to local implementation, it has long been the consensus that zoning is most properly done on a local, and occasionally, regional basis.

As demonstrated many times in this study, natural conditions, hazard, settlement, and economy all vary tremendously even within short distances. Three very different communities were found adjacent to each other and studied intensively for that reason: Cape May, Wildwood Crest, and Villas in New Jersey. Regulation of land use by zoning ordinance or subdivision regulation should differ in each community. Yet there are two classifications suggested in this study that can provide a general framework for zoning legislation, the details of which might differ from place to place. Such a framework is offered in table 6-9.

Table 6-9

A Framework for Zoning for Tidal Flood Damage Reduction

Hazard Zones	Functional Uses		
	Coast-Based	Coast-Oriented	Footloose
Prohibitive	x		
Restrictive	x	x	low damage use only
Warning	x	x	x

x = Use permitted

In Chapter IV, three types of hazard zones were suggested for the shore based on experience in riverine flood plains: a prohibitive zone, a restricted zone, and a warning zone. These may be illustrated in a sample application using local elevations resulting from a model hurricane zoning regulation suggested for use in Rhode Island.[1]

1. Prohibitive zone. For shores of southerly exposure all the area within 300 feet of the tide, below 20 feet msl, would fall within this zone. Only coast-based uses would be permitted.

2. Restrictive zone. All the area beyond 300 feet of the tide and above an elevation of 10 feet msl falls within the restrictive zone. All coast-based structures and coast-oriented structures are permitted. Footloose uses are discouraged but permitted if damageable property is minimal. All other footloose structures are not permitted.

3. Warning zone. This zone is all land not in the other two zones below 15 feet or the elevation of the standard project hurricane, whichever is higher. There are no restrictions in this zone. It is advisory only, and users are informed when they make application for building permits.

Several innovations might be used to introduce greater flexibility. Structures with deep pile foundations and surge-resistant anchorage might be permitted in a zone in which it is normally restricted by raising the critical elevation (usually the first floor) to the level of a permitted zone. Thus a properly built beach house might be permitted in the prohibitive zone if its first floor elevation exceeded 10 feet.

A community might want to permit for recreational purposes cheap cottage-type construction. Without compromising the basic zoning ordinance, two classes of structures might be created. These are permanent, to which the general ordinance applies, and temporary or expendable. Permits would be granted for this type of building even in hazard areas, provided: 1) the structures were occupied within prescribed seasons, 2) the owner acknowledged that the structure was subject to damage, 3) assumes responsibility for removal of debris in case of severe damage, and 4) agrees not to rebuild if severely damaged. This provision is designed to allow for recreational use within reach of lower income groups provided that undue burdens are not placed on the towns when severe storms arise.

This suggested framework seems to be within reach of any community, even those that are unable to provide maps with sufficient detail to delimit these zones. They can be stated in elevation with the burden on the would-be builder to demonstrate conformance. Maps of course are desirable, but for small communities without sufficient resources prompt action can still be taken.

Finally, the framework for zoning would appear to be legally sound. Although this is but a layman's judgment, it does embody what appears to the authors as the essence of a strategy for the human use of the shore: an acknowledgment of the awesome power of the ocean and a recognition of the age-old human need to come to the edge of the sea.

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[1] Rhode Island Development Council, op cit., p. VIII-3.

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